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PRODUCTION ENGINEERING RESEARCH

by Dr. D. F. Galloway, Wh.Sc., A.M.I.Mech.E., A.M.I.E.E., B.Sc.Hons.

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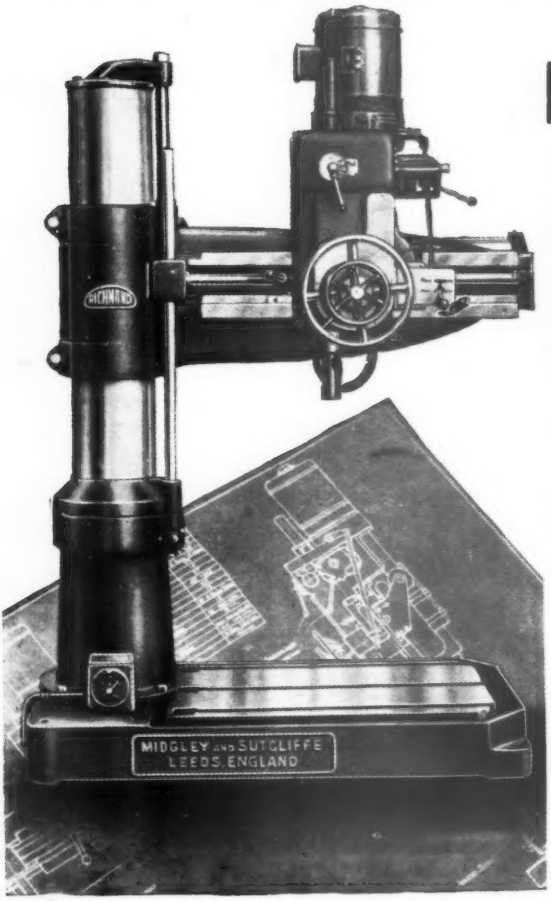

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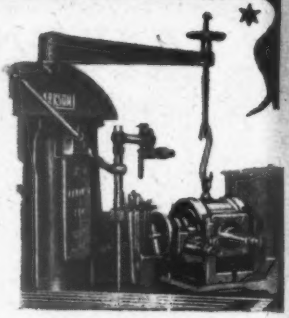

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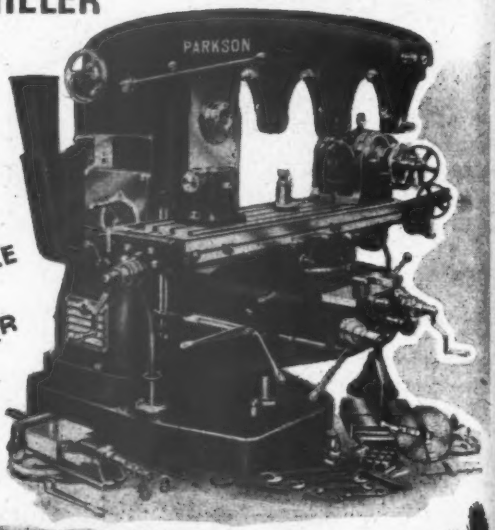

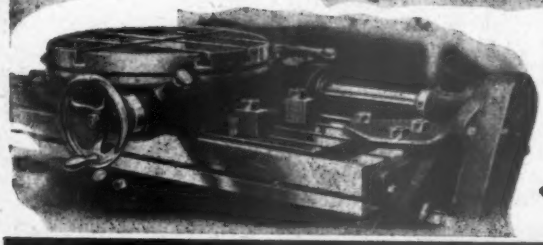

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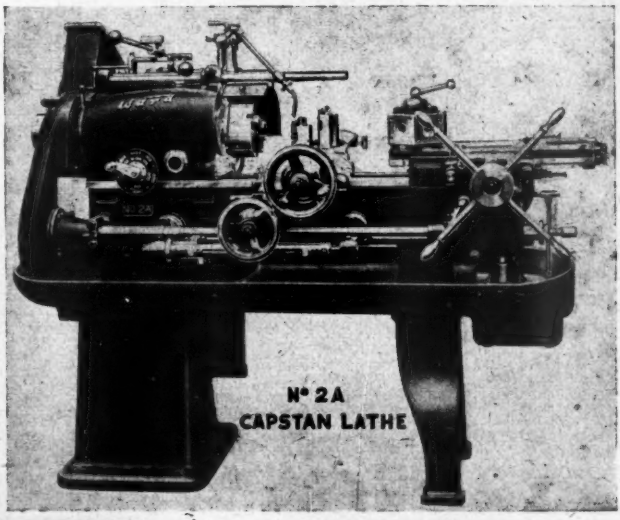

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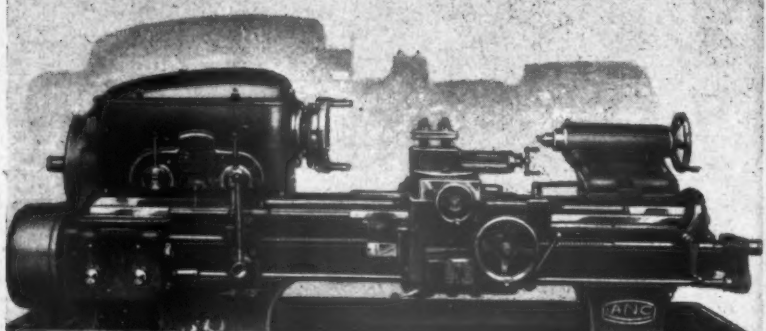

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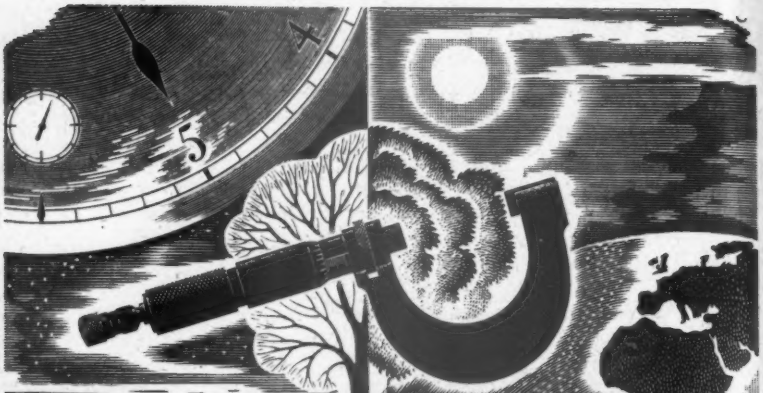

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PRODUCTION ENGINEERING RESEARCH

Paper presented to the Institution, Western Section, on 13th October, 1944, by Dr. D. F. Galloway, Wh.Sc., A.M.I.Mech.E., A.M.I.E.E., B.Sc.Hons.

Introduction—Scope of Paper.

DURING the development of the Institution's Research Department the following questions have been repeatedly asked by production engineers :

(1) What is production engineering research ?
(2) What results have been achieved by production engineering research ?
(3) How are these results obtained ?
(4) How are the results applied to industry ?
(5) What is the future scope of production engineering research ?

This paper consists of brief answers to these five questions

Definition and Objects of Production Engineering Research.

A rational definition of production engineering research is as follows :

" Production engineering research is investigation to discover facts and laws relating to the planning, control and execution of processes by which material is given a predetermined form with the aid of machines, tools, and labour."

The object of production engineering research is to obtain information which can be used to improve production ; by increasing the efficiency with which processes such as turning, drilling, pressing, die casting, etc , are carried out ; by improving the efficiency of auxiliary production activities such as material handling, swarf disposal, etc., and by improving such functions as production control, rate-fixing, planning, etc.

Results Achieved by Production Engineering Research.

Even with the restrictions imposed by limitations of available personnel, equipment, and floor space, the work carried out in the Research Department during the past five years has been so extensive that it is impossible to attempt to summarise it completely in a single paper. Turning investigations alone have involved tests on some 20 materials using about 50 types of steel and carbide cutting tools, not including several secret materials on which very

extensive tests have been conducted. A few research results have therefore been selected as representative of drilling, rough turning, finish turning and boring, grinding and special tests including sawing bronze and machining magnesium alloys.

Consider first some typical results obtained from drilling tests. An important factor in the efficient performance of many drilling operations is the selection of the most effective cutting oil. By

Cutting Fluid	Dilution	Drill life (Holes Drilled)
Oil 1	1 : 15	144
Oil 1	1 : 25	130
Oil 2	1 : 25	65
Oil 2	1 : 35	64
Oil 3	1 : 15	14
Oil 3	1 : 25	4
Dry	—	4

Data: Drill dia. $\frac{1}{4}$" speed = 760 r.p.m. = 1 4 f.p.m.
Feed = 0.014" per rev. = 10.6 in. per min. Depth = $1\frac{1}{4}$".
Drill material = "46" Substitute H.S.S.
Material drilled = Steel 0.25% C., 0.65% MN.
Normalized. 135 Brinell.
Rate of Coolant flow = 3 gallons per min.

Fig. 1.—Comparison of effects of various soluble cutting oils on drill performance.

carefully controlled tests it is possible to compare cutting oils on various bases, *e.g.*, investigation of the influence of the cutting oil on drill life between grinds. A comparison of various dilutions of three soluble oils used when drilling $\frac{1}{4}$" diameter holes in mild steel is shown in Fig. 1. Column 1 gives the oil number, column 2 the dilution in water as recommended by the oil suppliers, and column 3 the drill life, as measured by the number of holes drilled. Both the dilutions of oil No. 1, *i.e.*, 1 to 15 and 1 to 25 were better than either of the other oils. Changing dilution from 1 to 25 to 1 to 35 did not greatly affect drill life. It should be noted that the performance when using the worst oil was not superior to that when drilling dry.

The table Fig. 2 is similar to Fig. 1, but refers to straight oils and shows mean thrust and mean torque in addition to drill life. It is interesting to note that even very poor oils such as oils F and G effect improvements of the order of 50 to 150%, over the number of holes between grinds for dry drilling, and the use of good oils such as A and B increases drill life between grinds to approximately 10 times the life when cutting dry. The relation between drill life and thrust or torque is not consistent, but there is a tendency for both thrust and torque to increase as drill life is reduced by the use of inferior cutting fluids. Furthermore, the fluctuations of torque and thrust values are considerably increased by using inferior oils,

Cutting Fluid	Drill Life (Holes Drilled)	Mean Torque lb.ft.	Mean Thrust lb.	Remarks
Oil A.	105	16	1650	Very Smooth Cutting.
Oil B.	82	22	1500	Very Smooth Cutting.
Oil C.	70	20	1600	Smooth Cutting.
Oil D.	46	23	1750	Smooth Cutting.
Oil E.	35	22	1600	Smooth Cutting.
Oil F.	23	30	1650	Rough Cutting.
Oil G.	14	24	1750	Rough Cutting.
Dry	9	30	1750	Very Rough Cutting.

Data: Drill Dia. $\frac{1}{2}$" speed = 650 r.p.m. = 107 f.p.m.
Feed = 0.014" per rev. = 9.1 in. per min. Depth = $1\frac{1}{4}$".
Drill Material = "66" Substitute H.S.S.
Material Drilled = Steel 0.26% C., 0.65% mn.
Normalized. 146 Brinell.
Rate of Coolant Flow = 1.2 gallons per min.

Fig. 2.—Comparison of effects of various straight cutting oils on drill performance.

thus increasing the tendency to rough cutting as indicated in the remarks column of Fig. 2.

Examples of results obtained in rough turning investigations are given in Figs. 3 and 4. The main objectives in rough turning and the principal criteria by which the efficiency of such operations must be judged are :

(*i*) Rate of stock removal, *i.e.*, volume or weight of metal removed per minute.

(*ii*) Efficiency of stock removal, *i.e.*, volume or weight of metal removed per horse power-hour.

(*iii*) Tool life which should be given as the total volume or weight of metal removed between grinds, or may be given as the net cutting time before regrinding is necessary.

Examples of how these three important criteria are determined are shown in the specimen table of results, Fig. 3, in which the last three columns give respectively rate of stock removal in cubic inches per minute, efficiency of stock removal in cubic inches per horse power-hour, and tool life expressed as the total volume of stock removal which is the true criterion. From these test results, which relate to various grades of carbide tools consider the three inferior tools Nos. 6, 7, and 9. Tools 6 and 7 gave the same rate of stock removal, but the efficiency of stock removal and the tool life, expressed as total stock removal, was higher for tool No. 7 than for

tool No. 6. Comparing tool No. 7 with tool No. 9 it will be seen that, while the efficiency of stock removal remained approximately the same, the rate of stock removal and the tool life were superior for tool No. 9.

In addition to these three main criteria, others such as tool forces are observed, and the results so obtained serve as a basis not only for comparing tool grades, but also determining optimum conditions of

Tool No.	Depth ins.	Feed Per rev. ins.	Material	Cutting speed f.p.m.	Tool life min.	Gross input h.p.	Rate of Stock removal cu.in. per min.	Efficiency of stock removal cu.in. per hp.hr.	Tool life Total stock removal cu.in.
1	.157	.042	Shell No.1.	210	62	14	16.6	71	1,020
2	.470	.042	Shell No.1.	210	61	35.4	50	87	3,100
3	.375	.042	Ni.Cr. No.1.	175	57	21.2	33	93.5	1,870
4	.375	.042	Shell No.2.	180	71	28	34	73	2,400
5	.125	.021	M.S. No.1.	400	87	13.7	12.6	55.4	1,090
6	.188	.021	M.S. No.1.	250	34	16.6	11.8	42.6	404
7	.188	.021	M.S. No.1.	250	63	12.1	11.8	58.4	747
8	.188	.021	Mn-Mo No.1.	200	57	16.7	9.5	34	536
9	.188	.021	M.S. No.1.	316	60	16.1	15.0	56	910
10	.125	.031	M.S. No.2	396	60	12.8	18.4	86.5	1,100
11	.250	.031	M.S. No.2.	327	60	20.9	30.3	87.2	1,820
12	.375	.031	M.S. No.2.	304	60	29.1	42.5	88.0	2,550

Fig. 3.—Example of rough turning test results.

feeds, speed, depth, type of coolant and rate of flow, tool shapes including angles of rake, relief, etc. The relations between side rake and the three main components of cutting force are shown in Fig. 4, from which it can be seen that the tangential force T, feed force F, and radial force R are all reduced by increasing side rake. Three graphs of T are given corresponding to three values of back rake, and the relative position of these curves shows that increase of back rake also reduces the tangential component of cutting force.

Later, an example of how force measurement assists machine design will be shown.

In finish turning operations rate or stock removal and efficiency of stock removal are unimportant, since the depth of the finishing

Material Turned—Magnesium Alloy—As Cast.
Feed .012" per rev. Depth .060". Cutting speed 1,000 f.p.m. No coolant.

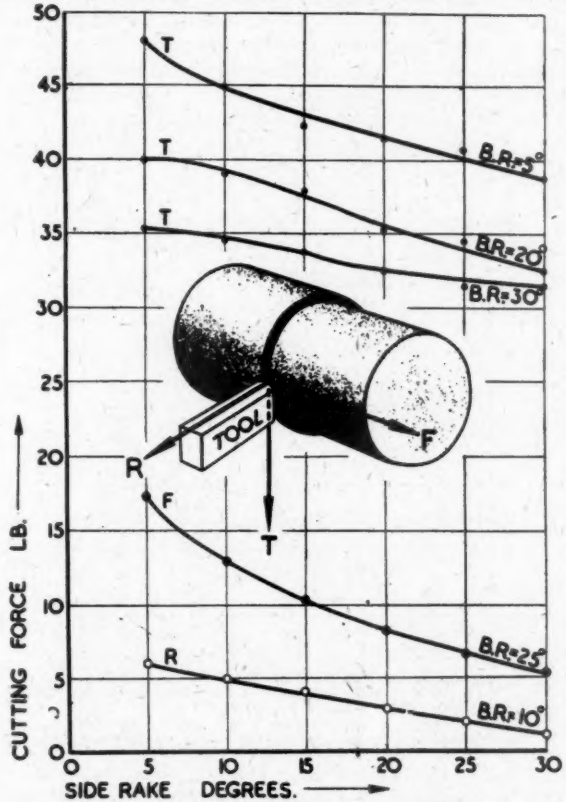


Fig. 4.—Relation between cutting forces and side rake.

cut can easily be reduced to a minimum by adjusting the cut and the pre-finishing operation and the power required to run the machine idle far exceeds the extra power required for cutting. In

place of these we have important objectives such as :

(*i*) Dimensional accuracy.
(*ii*) Quality of surface finish attainable.
(*iii*) Rate of production of components, which is dependent on rate of production of surface area of the required quality.
(*iv*) Tool life, which should be given as the total surface area of the required quality produced between grinds or may be given as the net cutting time under known conditions before regrinding becomes necessary.

Typical results of tests to determine the best cutting speeds, when finished turning non-ferrous alloys, are shown in Fig. 5. The curves for this particular cast aluminium alloy when turned with

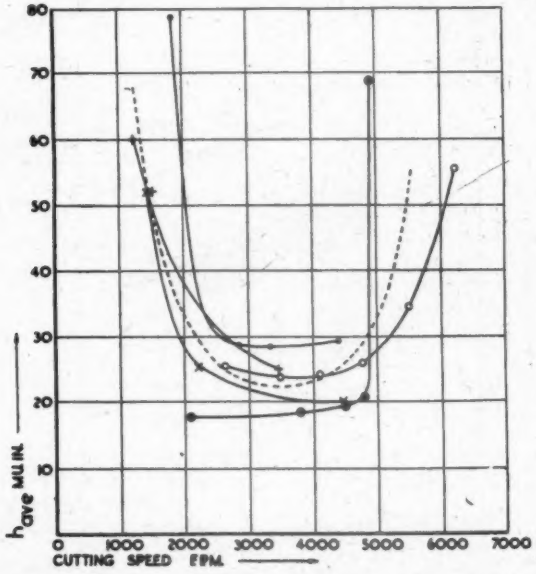


Fig. 5.—Relation between surface finish and cutting speed when finish turning cast aluminium alloy.

carbide tools all tend toward a U-shaped characteristic as indicated by the mean curve which is shown dotted. Thus when finish turning this particular alloy under the given machine conditions, there is a range of cutting speeds from about 2,000 to 5,000 f.p.m. within which the best surface finish is obtainable. For speeds above or below this range the surface finish rapidly deteriorates.

A more general impression of the results obtained from this type of test is given in Fig. 6, which shows the relations between cutting speed and surface finish for cast and extruded aluminium alloys turned first with cemented carbide, and then with diamond tools. At the side of the U-shaped curve, similar to that referred to above, is a graph showing the relationship between h_{ave} and cutting speed for the same cast aluminium alloy, when turned with a diamond tool. This characteristic differs markedly from that for the carbide tool, and takes the form of an inclined straight line. It will be noted that the graph immediately below, which refers to an extruded

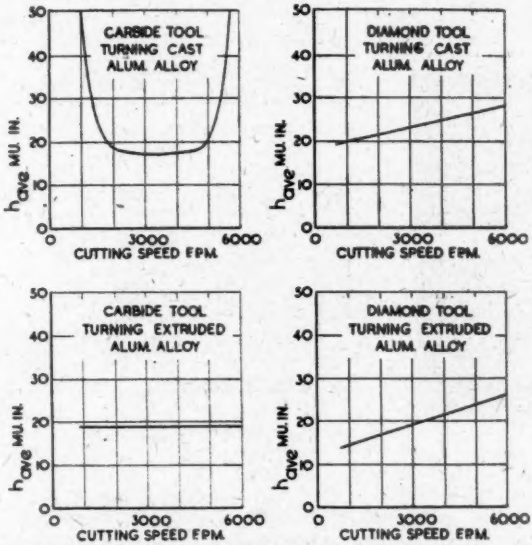


Fig. 6.—General characteristics showing variation of surface finish with cutting speeds for various aluminium alloys and cutting tools.

alloy turned with a diamond tool, is of the same form, whereas the same alloy turned with a carbide tool gives a characteristic as shown in the bottom left hand corner of Fig. 6, there being no variation of surface finish throughout the whole range of cutting speeds tested. In all cases the height of such curves, *i.e.*, the range of surface finish within which they lie, is dependent to a large extent on the design and condition of the lathe, particularly the headstock and tailstock bearings. Nevertheless, the forms of the characteristics are independent of machine conditions within the limits of good practice. Other alloys have other characteristics.

Results of some very lengthy and informative finish turning tests are given in Fig. 7. The upper graph shows the variation of surface finish throughout tool life when turning an extruded aluminium alloy with a carbide tool at 1200 f.p.m., 0.0005″ feed/rev. and 0.002″ depth of cut. The surface finish, which was initially 10 mu. in. gradually improved to 3 mu. in. during the first 20 hours of net cutting time,

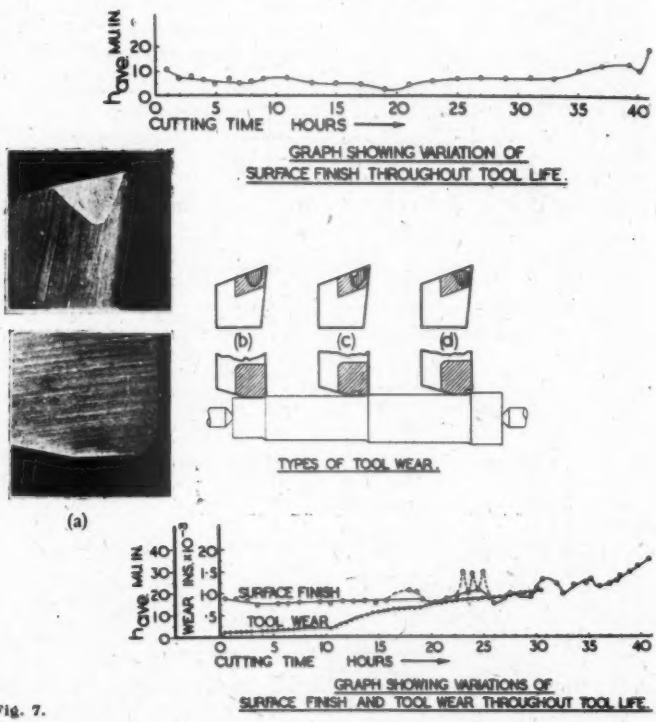


Fig. 7.

and then deteriorated until after 40 hours there was a sudden rise of h_{ave} to over 20 mu. in. The lower graphs are the results of a similar test in which tool wear was measured in addition to surface finish. The surface finish again improved slightly during the first few hours and then remained almost constant until after 15 hours when fluctuations of h_{ave} commenced. After approximately 19 hours the tool recovered and produced a uniform surface finish until at 23

hours cutting time very marked fluctuations of h_{ave} occurred. Despite the deterioration in surface finish the test was continued until after a total of 40 hours net cutting time h_{ave} had risen to almost 40 mu. in.

The tool wear graph has three main sections. First, the wear of about 0.0001″ which occurred in the first half hour as the initial sharp edge of the tool was rapidly removed. Secondly, a period of about 10 hours duration in which a steady rate of wear of about 0.00001″ per hour was maintained so that after 11 hours net cutting time the total wear was approximately 0.0002″, and thirdly, a much higher rate of wear, so that total wear was 0.0011″ after 30 hours net cutting time. It is clear that having regard for both tool wear and surface finish the economical life of the above carbide tool was about 11 hours, so that even under conditions of continuous cutting it would only be necessary to provide for regrinding once each shift and in ordinary practice where handling of the work-

CUTTING CONDITIONS : Turning Ni.Cr. Steel. Brinell Hardness 230. U.T.S. 60 tons per in². Speed 3000 f.p.m. Feed .004″ per rev. Depth .008″.

Machine used	Tool Used	Material Turned	Average Surface Finish mu. ins.	Tool Life mins.	Type of Failure
Lathe with reconditioned bearings but worn guides, etc.	A	Billet 14	110	9	Edge Spalled
New Lathe	A	Billet 14	60	60	Edge worn

Fig. 8.—Improvement of tool life and surface finish by use of superior machine tools.

piece, etc., takes a considerable part of the total time per component, regrinding every second shift would be sufficient.

Many other important results were obtained from these long duration tests, including valuable information on the development of tool failures. These cannot be discussed in detail in this paper, but the photographs and diagrams in the middle of Fig. 7, show typical forms of failure for carbide tools. The photographs (*a*) show plan and elevation of a tool tip worn flat after finish turning tough pitch copper at 0.0005″ per rev. feed, and 0.003″ depth. Diagrams (*b*) illustrate the same type of failure, which does not involve any spall. The normal type of failure which occurs when finish turning or boring ferrous and non-ferrous alloys with carbide tools starts as a dulling of the active part of the cutting edge followed by the formation of a flat on the tool flank below the worn edge (*b*), and finally if the tool continues in use a spall occurs,

usually at the front (*d*) or rear (*c*) of the worn flat. Considerable economy in tools is effected by regrinding before spalling occurs.

The considerable increase in tool life and general improvement in performance that can be effected by the use of superior machine tools is shown in Fig. 8. In these tests two lathes were used for the turning of the same Ni.Cr. steel bar with the same tool. In addition to improved quality of product, use of the better lathe increased tool life six times and the final tool failure was much less drastic.

Very extensive tests on the use of diamond tools have been carried out in the Research Department during the past four years. One of

Fig. 9.—Diamond tool in swivelling tool post.

the many interesting results concerns the effect of tool orientation with respect to the workpiece. Fig. 9 is a photograph of a diamond tool set in the swivelling tool post of a diamond turning lathe preparatory to a parallel turning operation. By means of the scale graduated in degrees, (Fig. 9) it is possible to adjust accurately the section of the tool cutting edge applied to the workpiece. Tests were carried out with both facetted and round-nosed tools at various settings of the degree scale, so that turning took place with the tool inclined at various angles to the axis of the workpiece. The effects upon surface finish obtained with various inclinations of a facetted

tool are shown in the upper half of Fig. 10, and those with a round-nosed tool in the lower half. For the facetted tool four graphs have been plotted, all for the same series of tool inclinations, but three based on actual test results at 0.0005″, 0.0015″ and 0.0025″ per rev. feed, and the fourth (dotted) part of the theoretical curve corresponding to the 0.0025″ per rev. feed. All curves fall to a minimum value of h_{ave}; as each facet of the diamond tool becomes parallel to the turned surface of the workpiece. Between these minimum readings there are maxima which indicate that the surface finish becomes roughest when turning with two facets equally inclined to the workpiece. The small illustrations on the graphs

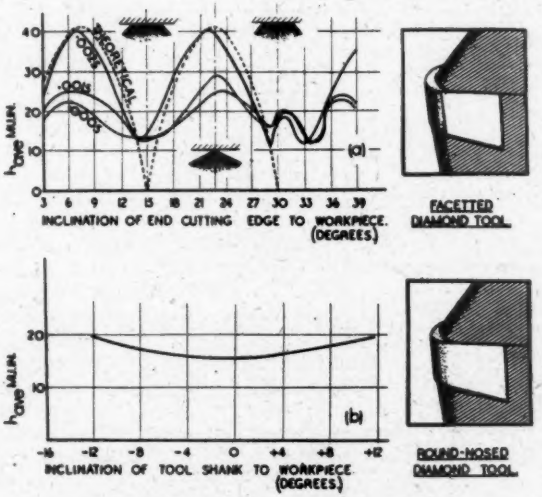


Fig. 10.—Variation in surface finish for different orientations of (a) a facetted tool (b) a round-nosed diamond tool.

indicate roughly the position of facets corresponding to maximum and minimum values of surface finish produced. Most of the facets on the particular diamond tool used were inclined to each other at 15 degrees, but two facets were inclined at only 3 degrees, and the resultant rise and fall of surface within 3 degrees rotation of the tool are shown with remarkable clarity near the end of the test graphs. It is also interesting to note the similarity between theoretical and practical curves broken only by the fact that factors other than tool orientation limit the minimum values of surface finish attainable under the given machine conditions to more than

10 mu. in. Under better machine conditions the form of the graphs remain the same, but the minimum values of h_{ave} are much lower.

In the case of round-nosed tools there is no great variation of surface finish corresponding to different settings of the tool as shown in the lower half of Fig. 10. Near the best setting, variations of ± 4 degrees have negligible effects on the surface quality produced.

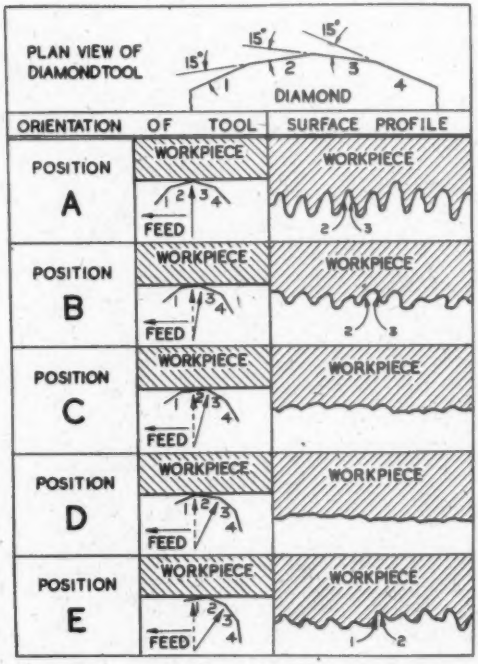


Fig. 11.—Orientation of facetted diamond tools.

Fig. 11 shows by means of pen records the same effects of tool orientation as were shown in Fig. 10. The second column shows the various positions A to E of the facetted diamond tool, and the third column shows the surface profile resulting from turning with the tool set in each of the given positions. For convenience, pen records are arranged to give distorted records of surface profiles, and allowance must be made for this distortion when interpreting the records in Fig. 11. The low horizontal magnification of the records makes the grooves appear narrower and deeper than they are in reality, but despite this it is clear that for position A the sides of the surface grooves marked 2 and 3, and the diamond tool facets 2 and 3, are equally inclined to the axis of the workpiece, whereas for position B, facet 3 and the sides of grooves produced by that facet, are more steeply inclined to the axis of the workpiece than facet 2, the leading facet, and corresponding groove sides. As the tool is rotated to other settings (positions C and D), facet 2 becomes almost

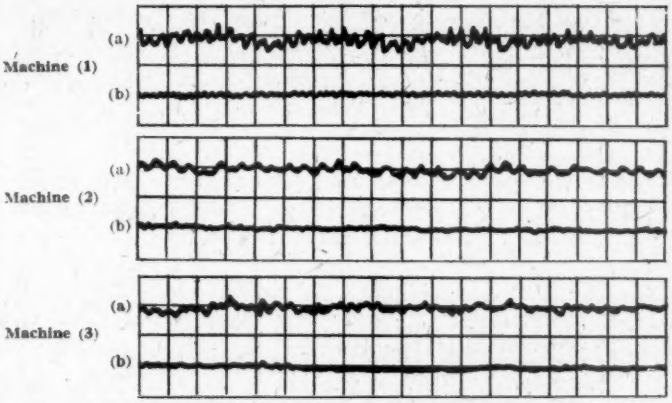


Fig. 12.—Longitudinal variation of various milling machine tables under similar cutting conditions.

parallel to the surface of the workpiece, so that the grooves become very shallow and good surface finish results.

At D facet 3 ceases to be operative, facet 2 becomes the trailing facet, facet 1 the leading facet, and the whole cycle is repeated with facets 1 and 2 replacing 2 and 3.

Milling is an operation in which it is important to reduce vibration to a minimum, and consequently vibration records are a very useful aid when testing and comparing milling machines. Copies of records taken from three machines performing the same rough milling operation are shown in Fig. 12. The amplitude of vibration is obviously much smaller for machine 3 than for machine 1, a factor which would affect considerably the smoothness of machining.

Width of cut 3¼". Depth .010". Speed 120 f.p.m. Feed 1.1 in. per min.
Cutter : H.S.S. Slab Mill. 4" wide. 10 teeth.
Material : Steel .26% C, .65% Mn. Normalised. 140 Brinell.

Cutting oil and dilution	Average Quality of Milled Surface *have* Mu. in.
Soluble Oil A. 1 : 40.	18
Soluble Oil B. 1 : 40.	20
Soluble Oil C. 1 : 40.	22
Straight Oil A.	25
Straight Oil B.	26

Fig. 13.—Finish milling with various straight and soluble cutting oils.

In milling operations the selection of the most effective coolant is often important. Results of finish slab milling tests on steel given in Fig. 13 show that for the three soluble oils and two straight oils used all the surface finishes were in the same class, namely, 16 to 32 mu. in., although the surface produced using soluble oil A at a dilution of 1 to 40 were near the low limit, and those using straight oil B were near the high limit.

While discussing classes of surface finish and comparing variations in h_{ave} it is desirable to ensure that this matter is seen in the right

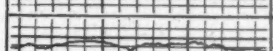
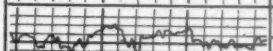
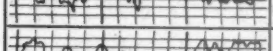
PEN RECORDS Vert. Scale 10,000 x. Horiz. Scale 200 x.	AVERAGEMETER READINGS h_{ave} mu. in.					MEAN h_{ave} mu.in.	TOTAL VARIATION %
	1.0	1.0	0.8	0.8	0.9	0.9	22
	0.9	1.0	0.9	1.0	0.8		
	1.9	2.0	1.9	1.8	1.8	2	20
	2.2	2.2	1.8	2.1	1.9		
	4.2	4.2	3.8	3.7	3.9	4	20
	3.9	4.1	4.2	4.5	3.9		
	8.0	8.5	8.0	7.6	7.8	8.1	17
	8.1	7.6	7.9	9.0	8.2		
	16	16	16	14	13	14.8	20
	14	15	15	16	13		
	32	33	34	34	33	32.2	16
	31	34	32	30	29		

Fig. 14.—Examples of various qualities of surface finish produced by finish grinding under very carefully controlled conditions giving extremely low total variation of h_{ave}

perspective. The economic aspect of surface finish must be carefully considered. If this is done the finishes selected for any component will normally be the coarsest finish permitting ease of assembly, proper functioning with mating parts, and adequate life. It is neither possible nor necessary in ordinary practice to control surface finish to the same fine tolerances as other quantities such as dimensions of workpieces or analyses of materials. Standards have been established for classes of surface finish in which the higher limit of acceptance within any class is approximately twice the lower limit. Thus, with class limits of 1, 2, 4, 8, 16, 32, etc., mu. in., it is possible for surfaces of 31 mu. in. to be accepted as in the same class as

surfaces of 17 mu. in. Should these limits seem excessively wide consider the examples of grinding results given in Figs. 14 and 15.

The finish ground specimens to which the pen records and average-meter readings in Fig. 14 refer, were produced by finish grinding under very carefully controlled conditions. Despite this it will be seen that the total variation in surface finish, expressed as :

$$\frac{\text{max. } h_{ave} - \text{min. } h_{ave}}{\text{mean } h_{ave}}$$

is of the order of 20%. In fact it is extremely difficult and requires a measure of control beyond that possible in normal practice to maintain such close limits as $\pm 10\%$. Normal practice with average care gives results such as those shown in Fig. 15. These were selected from a very extensive series of grinding tests during which two grades of finish were maintained, the rougher grade given by graphs (*a*), and the finer grade by graphs (*b*). The first

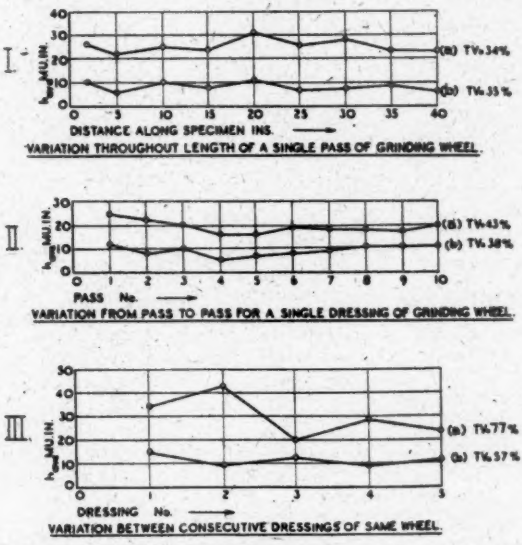


Fig. 15.—Variation of surface finish occurring in practice for finish grinding and fine finish grinding.

graphs (1) show the values of h_{ave} measured at intervals along the surface produced on a steel roll about 8″ diameter and 40″ long, by a single pass of the grinding wheel. The variation of h_{ave} from point to point was irregular, and the total variation approximately

the same for the rougher and finer grades, (*a*) being 34% and (*b*) being 35 %. The mean values of surface finish for each of a series of passes made without redressing the wheel were then plotted in chart II. This variation of the mean h_{ave} from pass to pass was

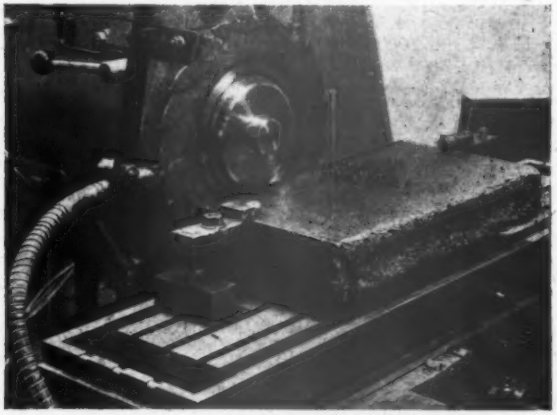


Fig. 16.—Sawing gated ends of tough "Kuniel" brass slabs.

also irregular and gave rise to total variations of 43% for (*a*) and 38% for (*b*). Finally, the averages of all surface finish readings taken between successive dressings of the same wheel were plotted at III. The variation was again irregular and the total variations increased further to 77% for (*a*) and 57% for (*b*).

Many special investigations have been carried out during the war, some on secret operations, others on particular operations such as removing the gated ends of very tough "Kunial" brass slabs by sawing with carbide toothed saws as shown in Fig. 16, and the face milling of magnesium alloy slabs, with carbide tipped fly cutters, as shown in Fig. 17.

Methods and Equipment for Production Engineering Research.

Three important requirements for effectively carrying out production engineering research are : (1) practical working conditions for tests, (2) rigid control of all factors not intentionally varied, and (3) reliable dynamometers and instruments for the accurate measurement of power, forces, torques, surface finish, and other relevant quantities so that comparisons of cutting oils, or tools, or machines, or machining conditions, etc., are removed from the realm of per-

sonal opinions or conjecture to that of the clear discrimination made possible by precise measurement.

The second requirement, namely, keeping as constant as practicable all factors except the intended variables, is one which entails an

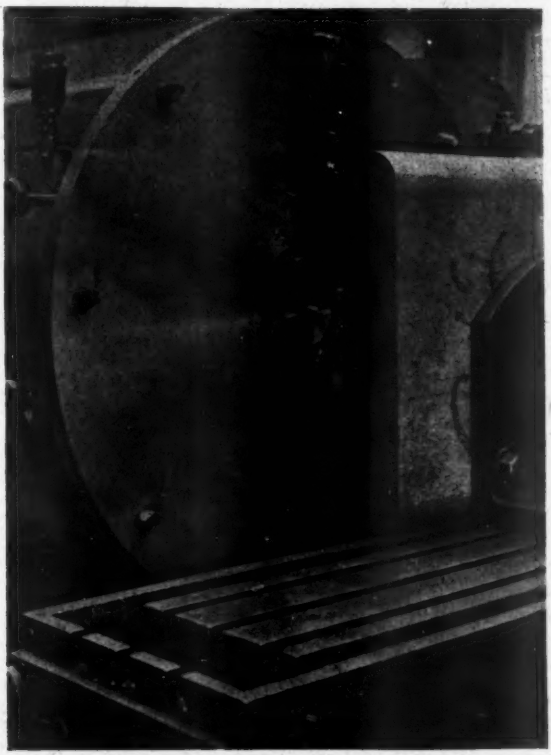


Fig. 17.—Face milling magnesium alloy slabs.

immense amount of work and patience on the part of the technical research personnel who, only after long experience, develop a sense of the numerous factors involved in apparently simple operations, and acquire practical knowledge of how to control these factors. The importance of this second requirement will be appreciated after a perusal of Figs. 19 and 33, which show some of the factors involved in drilling and turning respectively.

Drilling Research.

The main criteria by which drill performance is judged are :

(*i*) Rate of penetration, *e.g.*, depth of hole drilled per minute.

(*ii*) Drill life, usually expressed as depth drilled between grinds. It is also necessary to consider total drill life, *i.e.*, total depth before the drill is discarded. These two criteria are not in the same ratio for different drills and drilling conditions.

(*iii*) Drilling efficiency expressed as volume of metal removed per horse power minute or as power required for a given rate of drilling.

(*iv*) Accuracy of holes, *i.e.*, diameter, straightness, etc.

HARDNESS OF DRILL LANDS DPH. NO

DRILL	LAND	A	B	C
I	1	927	927	598
	2	966	927	618
II	1	823	823	598
	2	823	736	598
III	1	856	800	685
	2	856	856	736

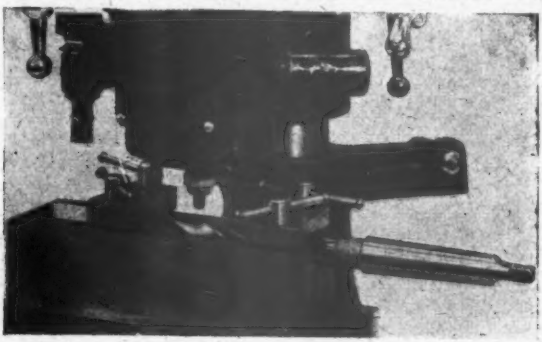


Fig. 18.—Hardness testing of drills.

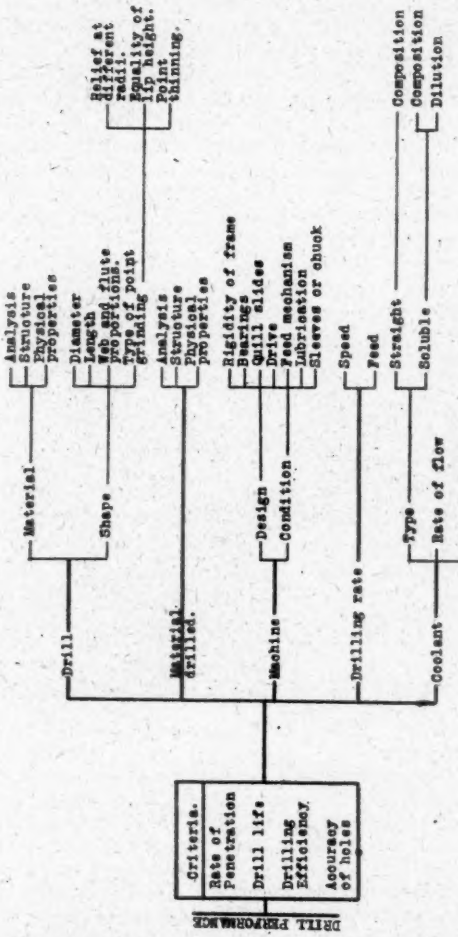


Fig. 19.—Factors affecting drill performance.

These criteria are given in Fig. 19 together with the main factors affecting drill performance, namely, drill used, material drilled, machine used, drilling rate and coolant used.

Drills differ according to the material of which they are made. They also differ according to their shape including diameter, pro-

portions of web and flute, etc., determined by the manufacturer, and the type and accuracy of drill point including relief, point thinning, equality of lip height, etc., which can be controlled by the user when regrinding. Material drilled may vary in analysis, structure, or physical properties depending on the homogeneity of the original billet or other factors such as subsequent heat treatment. Drill performance is also dependent on the design and condition of the drilling machine, particularly rigidity of frame, spindle bearings, and other items as listed in Fig. 19. The two remaining factors are drilling rate as determined by feed and speed, and the coolant used, including type of oil, rate of flow, and method of application. These factors present a formidable list of possible variables, which if not

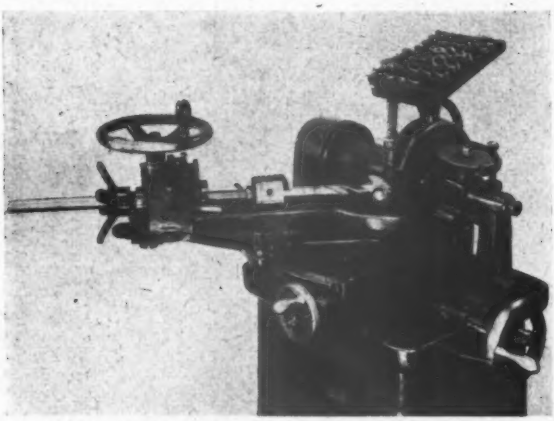


Fig. 20.—Drill grinder.

carefully controlled can vitiate test results in such a way that the effects produced by the intended variable, be it drill relief, coolant, etc., are completely masked. The problem of keeping constant all but the desired variable is extremely difficult but of profound importance.

The first main factor mentioned in Fig. 19 was the drill, and Fig. 18 shows how one of the physical properties, hardness, is checked. The drill is held in a special vee block and either clamped in position or cast in Wood's metal which can be removed by melting at 160° F. (70° C.). The usual indentation hardness tests are taken at intervals along the drill lands. An indication of the wide variations in hardness observed in commercial drills is shown in the table Fig. 18 which refers to three $\frac{5}{8}$" diameter drills tested on both lands at

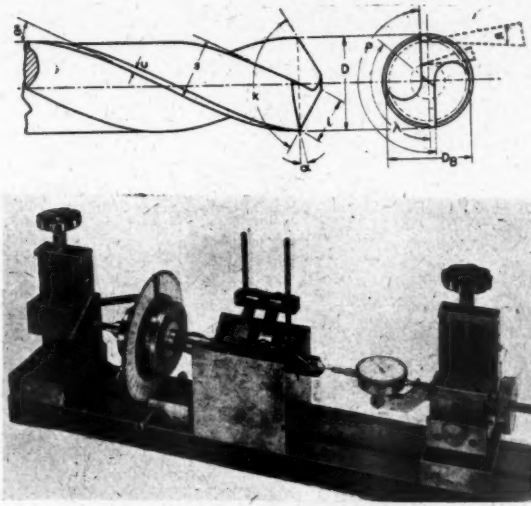


Fig. 21.—Drill point tester.

positions A, B and C. In addition to variations from drill to drill there were variations along individual lands and a marked reduction of hardness about two-thirds along the working length of the drill. This reduction greatly reduces the length available for testing, and in practice reduces the total depth of hole drilled before the drill has to be discarded.

Shape is a very important factor in drill performance and extreme care is taken when grinding drills required for test purposes. A "Hunt" drill grinder is used, and has been modified to facilitate control and to ensure the high standard of perfection and uniformity which is indispensible. The only modifications apparent in Fig. 20 are graduations on the upper operating handwheel which enable

Make of Drill	Drill Dia. at Point	Chisel Point Angle	Chisel Edge Angle	Relief Angle						Difference in Lip Height
				At $\frac{1}{8}$" rad.		At $\frac{1}{4}$" rad.		At $\frac{1}{2}$" rad.		
				Lip 1	Lip 2	Lip 1	Lip 2	Lip 1	Lip 2	
A	.6245"	118°	138°	11°30′	10°20′	14°20′	13°20′	22°30′	22°30′	.004"
B	.6248"	118°	136°	9° 0′	7° 0′	12° 0′	13°40′	24° 0′	23°40′	.005"
C	.6256"	127°	138°	20°10′	17° 0′	21°10′	19°50′	24°20	26° 0′	.011"

Fig. 22.—Variation between drills supplied by different makers.

drills to be set so as to give various distributions of relief along the lips, and the indicator near the handwheel on the right (Fig. 20), which facilitates consistent point thinning.

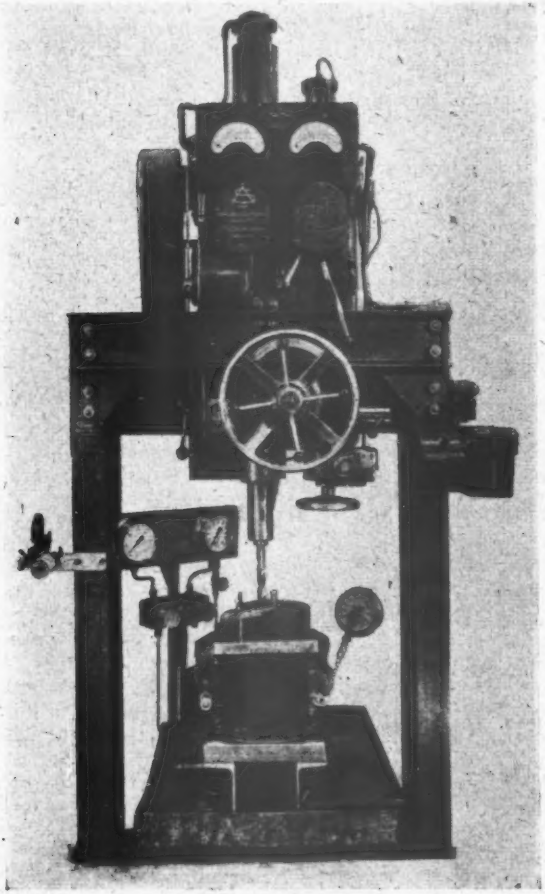


Fig. 23.—Drill testing machine.

By the use of special cams on the drill point grinder the required form is produced and is then checked in the drill point tester shown in Fig. 21. The various dimensions and angles which define drill

form are shown in the upper half of Fig. 21. One important factor not directly shown in Fig. 21 is equality of lip height which, together with the angle of relief *a* can be readily measured at various radii, using the point tester. This instrument consists of a vee block on which the drill rests while its shank end, carrying a special sleeve and circular protractor is held by springs against a stationary centre. In contact with the ground end of the drill is the sharp feeler of a $\frac{1}{10000}$ in. dial gauge which can be adjusted vertically and horizontally

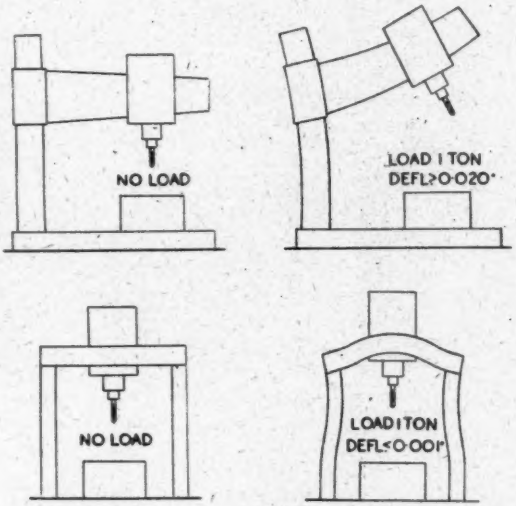


Fig. 24.—Deflection comparison of drill testing machine and radial drilling machine.

so that the feeler explores any required radius of the drill. The drill with its sleeve and protractor is rotated by hand, the exact angle of rotation being observed together with the corresponding relief indicated on the dial gauge.

For ordinary testing we maintain lip heights within 0.002" of equality, otherwise even with relatively coarse feeds the distribution of load between lips becomes very uneven, and drill performance is impaired. These limits may be compared with the variations common in practice, not only among drills that have been badly ground by careless users, but among drills as supplied from stocks of reputable makers. The table Fig. 22 gives variations in lip

height and values of relief for drills selected at random from supplies received from various makers. This table reveals many undesirable

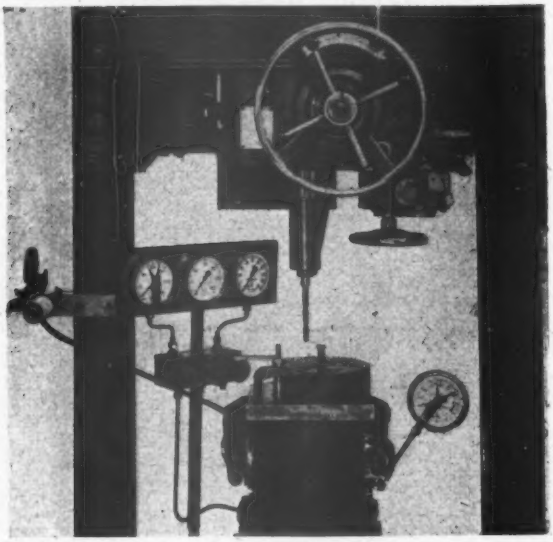


Fig. 25.—Drilling dynamometer set up for test.

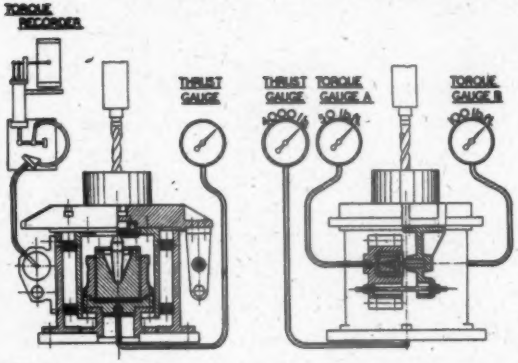


Fig. 26.—Drilling dynamometer.

features in these drills, but most noticeable is the inequality of lip height given in the last column. In practice, feed rates for $\frac{5}{8}$" diameter drills do not usually exceed 0.010" per rev., yet at this

value drills A, B and C would have a very ineven distribution of cut, a condition conducive to poor drill performance and frequent breakage.

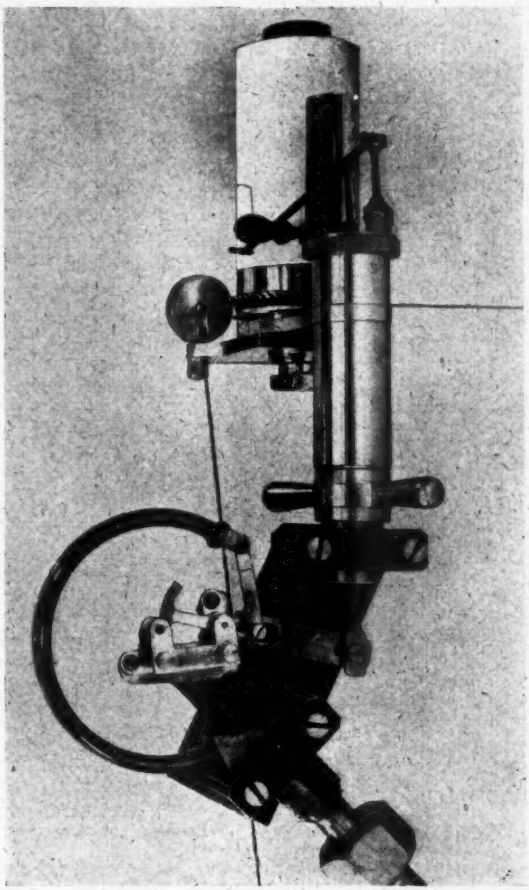


Fig. 27.—Torque recorder.

The material drilled is subject to the same rigorous control as the drill. Where necessary the billets are carefully normalised, checked for analysis, hardness and other physical properties.

One of the drill testing machines used in the Research Department is shown in Fig. 23 with a torque and thrust dynamometer supporting the specimen immediately below the drill. The dials on the gear box of the machine give spindle speed, motor current and power. This machine, loaned by Messrs. Adcock and Shipley, is

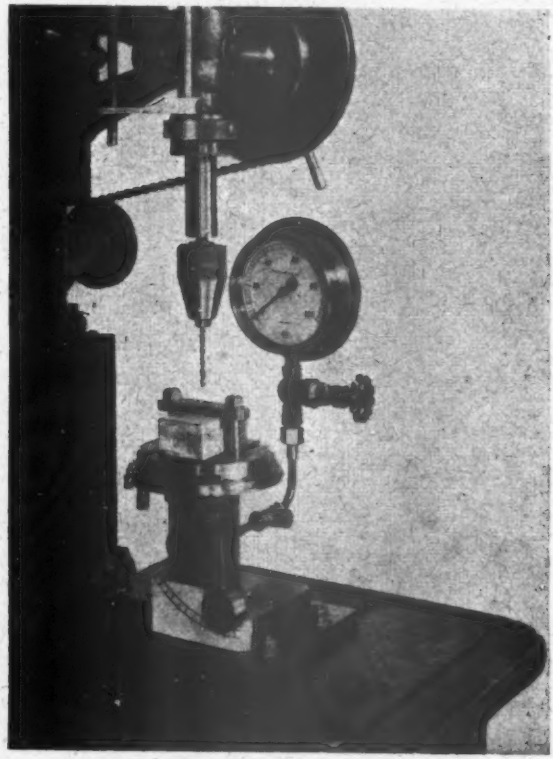


Fig. 28.—Small capacity drilling dynamometer set up for test.

specially designed for drill testing and has a portal frame. For test purposes, where the size of billet to be drilled can easily be controlled, the portal frame has immense advantages over the ordinary radial drill. Assuming a moderate drill thrust of 1 ton, the radial machine as shown at (*a*) Fig. 24, deflects as shown at (*b*), causing the machine head to move > 0.020″ and becomes inclined,

whereas the portal frame shown at (*c*) deflects as shown at (*d*), so that the machine head moves only < 0.001" and remains vertical.

Fig. 25 shows a close-up of the dynamometer in position with the specimen strapped to its table. The pressure gauges are calibrated

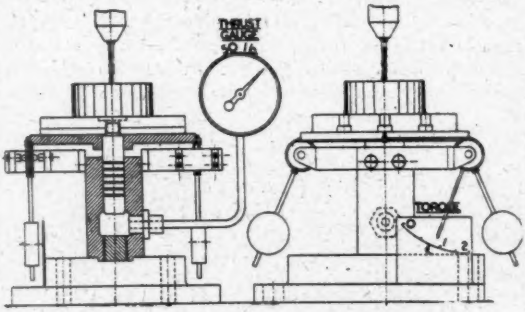
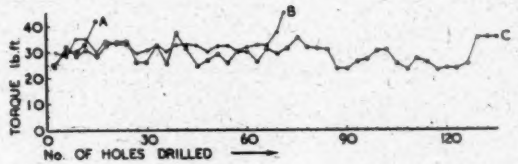


Fig. 29.—Small capacity drilling dynamometer.



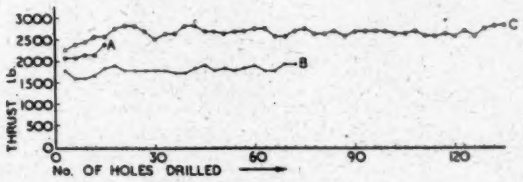
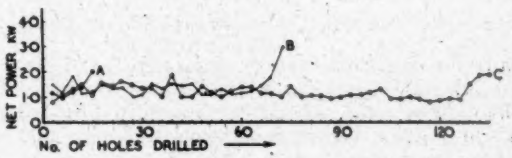


Fig. 30.—Drill life tests with soluble oils.



to indicate the torque and thrust on the drill during drilling and the automatic torque recorder is attached to the left hand upright of the machine.

An impression of how this dynamometer functions is given by the

diagrammatic section in Fig. 26. The specimen being drilled is shown fixed to the table of the dynamometer which, in the left hand diagram, is seen to press a thrust pin against the back of a piston. The lower end of the piston presses on a rubber diaphragm and thus compresses glycerine in the small space below the piston, the increase in pressure being indicated on the thrust gauge. By reference to the same diagram it will be seen that the table is free to rotate on ball and roller bearings and is only restrained by the arm shown on the right hand side of this diagram. The arm is shown

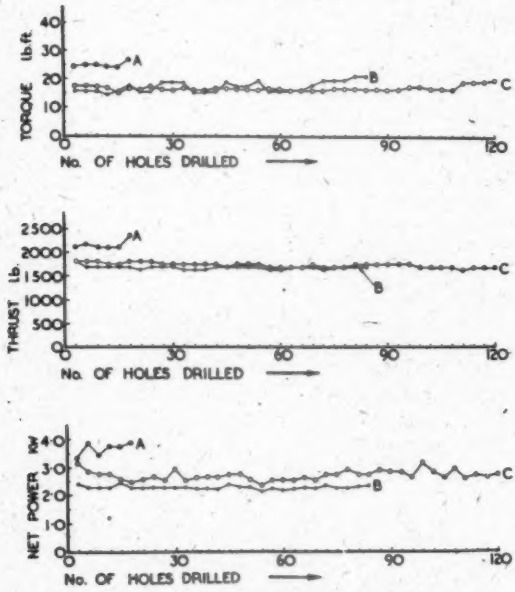


Fig. 31.—Drill life tests with straight oils.

in heavy lines in the centre of the right hand diagram. It presses on a thrust pin and piston which compresses glycerine and actuates the torque gauge, exactly as described for thrust measurement. There are two diametrically opposite pistons and cylinders in the torque measuring system. The thrust gauge has a range up to 4,000 lbs. and torque gauges can be used up to 50 lb. ft. or 100 lb. ft., or alternatively, one torque gauge can be replaced by the torque recorder shown on the extreme left, thus obtaining a graphical record of torque variations. A close-up of the torque recorder is

given in Fig. 27. The range of this dynamometer is suitable for tests on drills from $\frac{1}{2}''$ to $2''$ diameter, but for smaller drills involving correspondingly smaller values of thrust and torque a dynamometer such as that shown in Fig. 28 is used. This has a hydraulic system for thrust measurement and pendulums for torque measurement as can be seen by reference to the diagram in Fig. 29.

Typical results obtained from tests using the larger dynamometer are shown in Figs. 30 and 31. The first graphs in Fig. 30 show the variations of torque throughout drill life when using three different

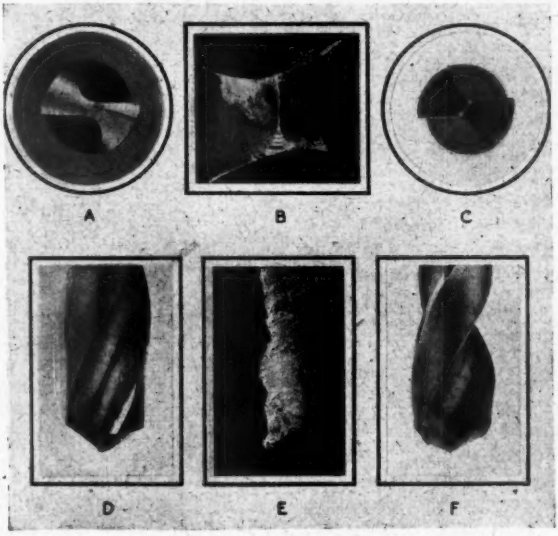


Fig. 32.—Types of drill failure.

soluble cutting oils, A, B and C under the same conditions. In these cases the end of drill life was clearly indicated by the marked increase in torque after 12 holes for oil A, 72 holes for oil B, and 135 holes for oil C. The variations in thrust were less erratic than torque and the graphs indicate a more gradual rise. The power graphs exhibit the same sudden rise at the end of the drill life as the torque.

The torque, thrust and power graphs for drilling tests, using a series of straight oils, are given in Fig. 31. In no case are the fluctuations so erratic as with soluble oils, and the rise of torque though quite apparent is not so great. According to the general procedure

adopted for drilling tests in the Research Department, drills are rarely considered to have failed because of rises in torque, thrust, or

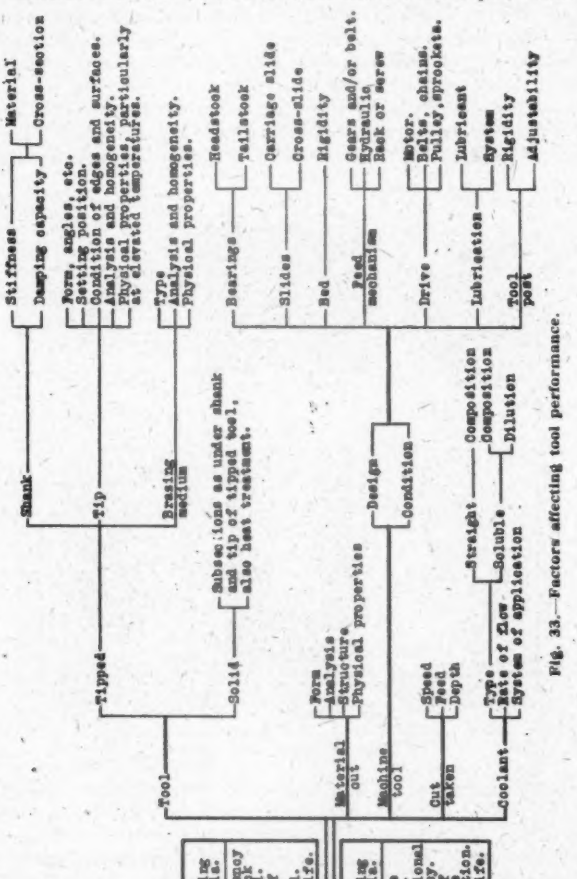


Fig. 33.—Factors affecting tool performance.

power alone. Such rises must be supported by other evidence such as that revealed by frequent visual inspection of the drill during

test. These inspections are carried out at least every 6 holes, and more frequently when a critical stage is reached. The inspection, though general, is directed particularly to the detection of wear at the chisel edge, along the lips and at the lip corners. Fig. 32 shows (A) a drill before use, (B) wear on the chisel edge, (C) wear on the chisel edge, along the lips and at the lip corners. Wear at the chisel edge is usually associated with a rise in thrust and wear at the lip corner usually causes a rise in torque. Sometimes wear occurs along the lands Fig. 32 (D)) and this causes an increase in torque as depth increases during the drilling of each hole. Fig. 32 (E) is an enlarged view of the wear on the drill land shown in Fig. 32 (D), and Fig. 32 (F) shows a drastic failure such as occurs when tests are continued beyond the point where failure is usually

Material to be Machined	Make of Tool	Diamond Hardness No.			Mean Hardness No.
		A	B	C	
Steel	1	1630	1720	1720	1690
,,	2	1630	1630	1540	1600
,,	3	1460	1540	1460	1485
,,	4	970	1010	930	970
Cast Iron	5	1630	1630	1630	1630
,, ,,	6	1630	1540	1540	1570
,, ,,	7	1540	1540	1540	1540
,, ,,	8	1340	1340	1460	1380

Fig. 34.—Hardness variation of carbide tools as supplied for machining a given material.

recognised. It is by accurate preparation and interpretation of records, such as are contained in Figs. 30, 31 and 32, that more general comparisons of immediate practical value such as were shown in Figs. 1 and 2 can be made.

Turning Research.

The investigator is again confronted with a formidable list of factors affecting tool performance (Fig. 33), which in this case must be judged by different criteria depending on whether the operation is rough turning or finish turning. These criteria, which are given on the left of Fig. 33, have been fully described on pages 89 to 94. Although the criteria are different for rough and finish turning, tool performance is dependent in varying degrees upon the same main factors which are set out in Fig. 33. Although the factors given are

made more numerous by such additional items as tipped tools, etc., the main groups are similar to those already described for drilling research.

Consider just a few of these factors. One test of the physical properties of the turning tools is measurement of tip hardness. Results selected at random are shown in Fig. 34. The excessive variation of tools supplied for the same job, by different carbide tool manufacturers is seen by reference to the mean diamond hardness numbers given in the last column. Another factor is tool shape, including angles of rake, relief, nose radius, etc. Fig. 35 shows how the

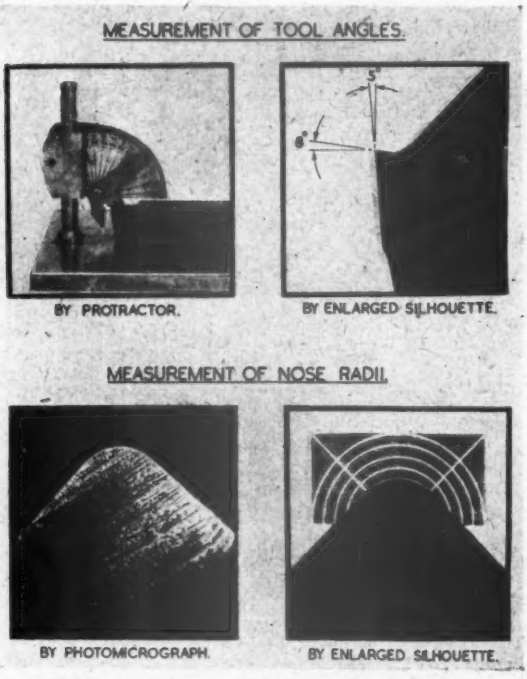


Fig. 35.—Measurement of tool angles and nose radii.

accuracy required for test purposes is controlled. Tool angles can be measured by a special tool angle protractor, but if greater accuracy is required or the tool tip is small as for diamond tools, enlarged silhouettes are used. The nose of the tool, where the side cutting

edge and end cutting edge join is of great importance, so that nose radii have to be carefully controlled to obtain consistent results. Photomicrographs or enlarged silhouettes can be used, although it is often not necessary to make actual photographs, but merely to

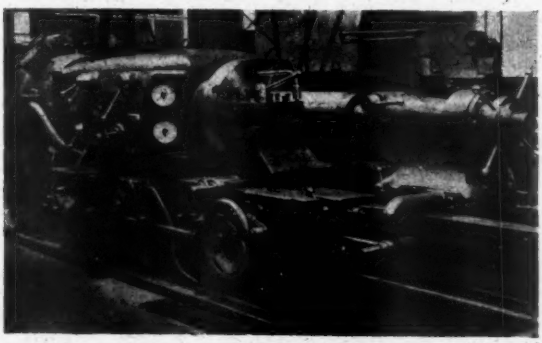


Fig. 36.—Heavy duty tool testing lathe.

focus the image on a ground glass screen and check the outline with a transparent radius gauge as shown in Fig. 35.

The heavy duty tool testing lathe used for turning tests is shown in Fig. 36. It has a centre height of 15″ and is driven by a 60 h.p. "Schrage" type motor giving infinitely variable spindle speeds from 10 to 1500 r.p.m. There are 18 feeds ranging from 0.00075″ per rev. to 0.080″ per rev. Fitted in the headstock of the machine is a tachometer and a wattmeter, both of which are dual range instruments to give the required accuracy of spindle speed and power consumption measurements. The machine is of robust construction, and the tool post is suitable for holding tools direct or a tool force dynomometer as shown in the plan view, Fig. 37. In this test set-up the tool dynamometer is held in the front tool post and is connected by a nine-core armoured cable to its instrument box which is situated near the headstock. The three main dials on that instrument box indicate the three components of the cutting force.

In the rear tool post is mounted an hydraulic Brinell press, specially developed for use in the tool testing lathe. By means of this equipment, hardness readings can be conveniently taken after each reduction of bar diameter, so that variations in hardness are immediately detected. The body of the instrument consists of a cylinder with a piston in each end and oil between them. One piston is forced into the cylinder by a differential screw which is

turned by the handwheel shown on the extreme right. The oil is thus pressed against the other piston, the rod of which carries the Brinell ball and can be seen projecting towards the cylindrical specimen. The Bourdon pressure gauge on the left of the handwheel indicates the oil pressure and hence the load on the Brinell ball.

The Brinell tester can also be used in conjunction with a portable frame to check the hardness of large specimens not in the lathe and beyond the capacity of ordinary Brinell hardness machines.

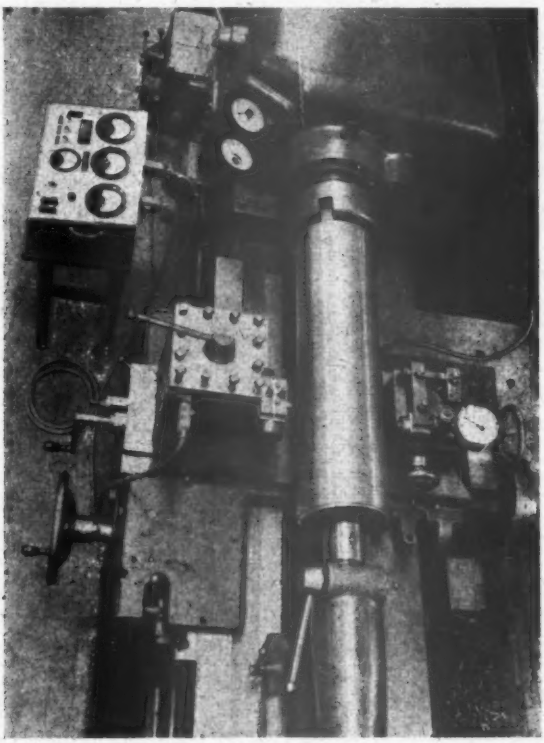


Fig. 37.—Set up for rough turning tests showing tool dynamometer and portable Brinell tester.

Another feature of interest, clearly seen in Fig. 37, is the heavy slotted driver which ensures a positive balanced drive. An impression of the design and mode of operation of the tool force dyna-

mometer can be gained from Figs. 38 and 39. These dynamometers are designed to measure the three mutually perpendicular components of cutting force illustrated in Fig. 4. The main component T is tangential to the workpiece, R is radial and F is in

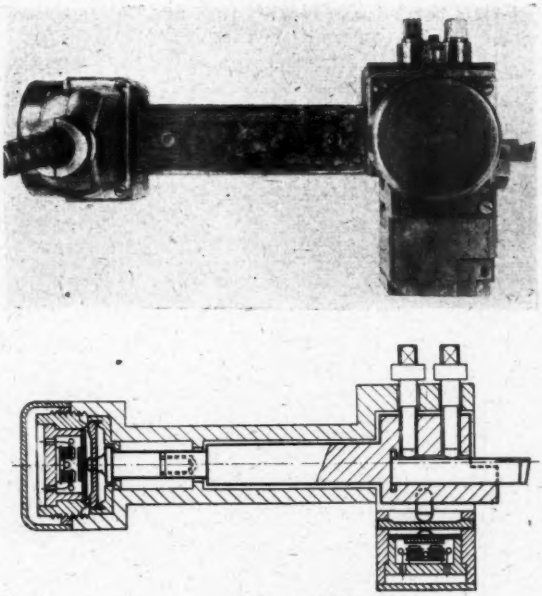


Fig. 38.—Lathe tool dynamometer.

the line of feed. These three components are measured by three electrical measuring elements, all of which can be seen in the close-up photograph of the dynamometer, Fig. 38. The feed force measuring element is beneath the circular cover immediately behind the tool, the tangential force measuring element is contained in the rectangular section extending below this circular cover, and the radial force measuring element is contained in the cylindrical cover on the extreme left, behind the armoured cable.

The mode of operation of the dynamometer is illustrated by the diagrammatic section in the lower half of Fig. 38. The tool, projecting on the right, is held in the central tool holder which, under the action of the cutting force, can move slightly downward, backward, and to the side. The tangential component of cutting force

presses the tool and tool holder downwards and the force is transmitted through thrust pins, one of which is shown below the tool, to the spring plate which deflects and actuates the measuring element. The arrangements for measuring the feed and radial components of the cutting force are similar except that the long shank of the central tool holder is fixed to the centre of the rear spring plate which is sufficiently flexible to permit such movements of the holder as are required to operate the measuring elements. The maximum movements are approximately 0.0005″ for each measuring element.

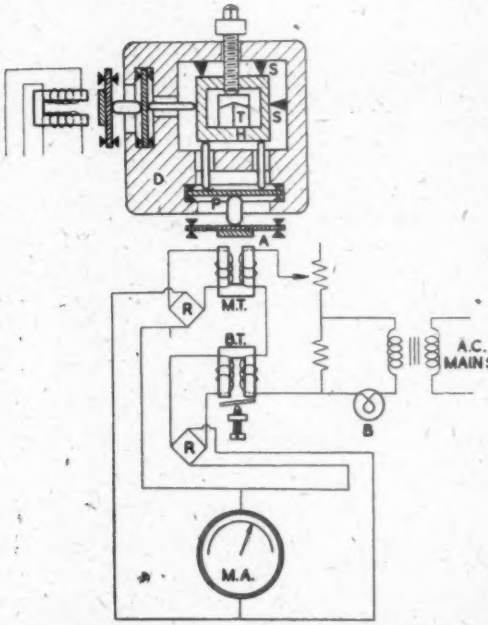


Fig. 39.—Cutting tool force dynamometer.

The general principles employed in this type of dynamometer are shown in the composite mechanical-electrical diagram, Fig. 39. The tool T is rigidly held in the central tool holder H which is located within the dynamometer body D by vertical and horizontal stops S, and the thrust rods. The tangential component of cutting force is transmitted by the vertical thrust rods which deflect the calibrated spring plate P, and, through a further thrust rod deflect the armature support A, thus reducing the gap in the measuring transformer M.T.

The primary of this transformer is in series with the primary of the balancing transformer BT, both being fed from the mains through a transformer and barretter (B). The secondary currents of both transformers are rectified (R) and their difference is measured on a micro-ammeter M.A. Thus the gap in the balancing transformer can be set at will to give the required zero reading and changes of

gap in the measuring transformer M.T., due to changes in the cutting force, are indicated on the micro-ammeter. Arrangements for measuring the radial and feed components are similar to those described above for the tangential component. The electrical circuit described above is in accordance with British Patent Speci-

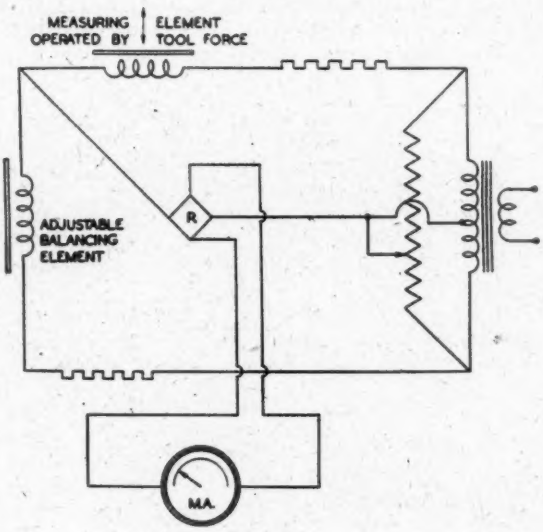


Fig.—40.

fication, No. 502,500. An alternative circuit which has been used is shown in Fig. 40.

Although the majority of force measurements have been confined to rough turning tests, *e.g.*, results given in Fig. 4, a very sensitive dynamometer was developed for the measurement of forces when finished turning, and an example of the interesting results obtained is given in Fig. 41. Cemented carbide and diamond tools were used under conditions such as are common in practice, with feeds varying from 0.0005″ to 0.0025″, and depths below 0.003″, so that the areas of cut involved were but a few millionths of a square inch, and the forces often only a few ounces.

The graphs on the left of Fig. 41 show the variation of cutting force as the product of feed and depth is varied when turning an extruded aluminium alloy, a cast aluminium alloy and two brasses. The graphs, particularly those for the aluminium alloys, are not

linear, *i.e.*, tangential force is not proportional to the product of feed and depth, so that specific cutting force which is

$$\frac{\text{tangential cutting force}}{\text{feed} \times \text{depth}}$$

is not constant for different areas of cut. This is clearly shown by the right hand graph from which it can be seen that specific cutting force becomes much greater as the product of feed and depth is

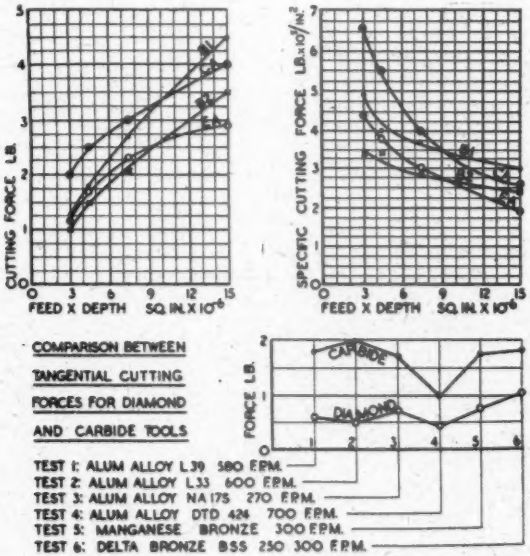

CUTTING FORCE LB.
FEED X DEPTH SQ. IN. X 10⁻⁶
SPECIFIC CUTTING FORCE LB. x 10³/IN.²
FEED X DEPTH SQ. IN. X 10⁻⁶
COMPARISON BETWEEN
TANGENTIAL CUTTING
FORCES FOR DIAMOND
AND CARBIDE TOOLS
FORCE LB.
CARBIDE
DIAMOND
TEST 1: ALUM ALLOY L.39 580 F.P.M.
TEST 2: ALUM ALLOY L.33 600 F.P.M.
TEST 3: ALUM ALLOY NA 175 270 F.P.M.
TEST 4: ALUM ALLOY DTD 424 700 F.P.M.
TEST 5: MANGANESE BRONZE 300 F.P.M.
TEST 6: DELTA BRONZE BSS 250 300 F.P.M.

Fig. 41.—Cutting forces for finish turning.

reduced. This is in conformity with results obtained in rough turning tests, both in the Research Department and by other investigators.

The difference in cutting forces involved when turning the same material under the same conditions, first with carbide tools, then with diamond tools, is remarkable. In all cases the cutting force is less for diamond tools than for carbide tools as can be seen from the series of results selected at random and plotted in the chart at the foot of Fig. 41.

Milling Research.

Research into any production process involves the investigation of a mass of dependent factors such as were shown for drilling (Fig. 19) and turning (Fig. 33), but those two examples must suffice and accordingly this section on milling research is restricted to brief references to two instruments not previously dealt with, namely, the vibrograph and the surface meter.

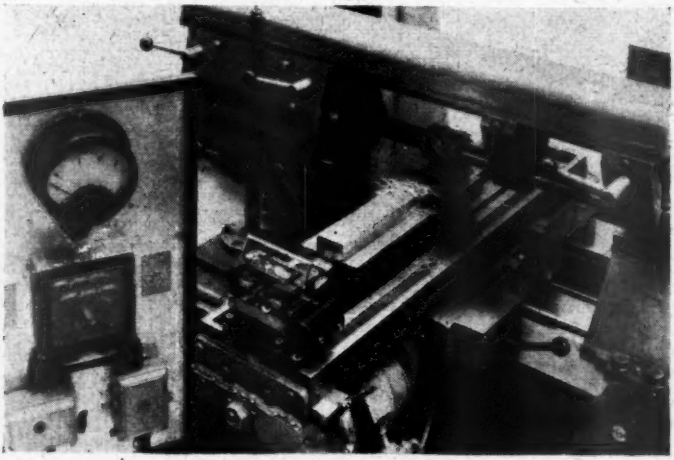
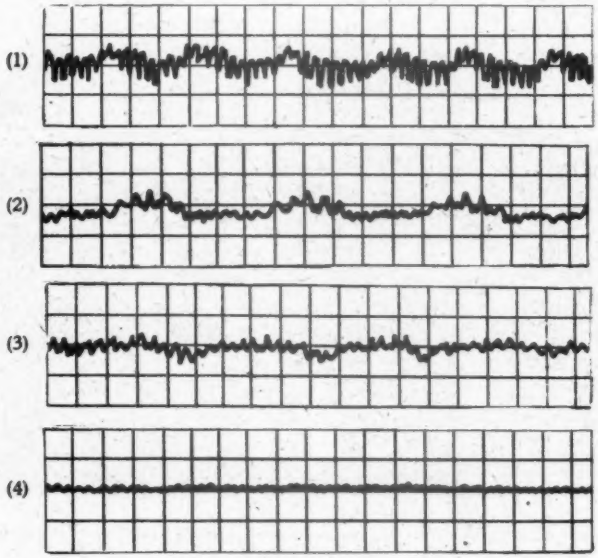


Fig. 42.—Vibrograph set up for measuring longitudinal vibrations of milling machine table.

The Cambridge vibrograph used in the Research Department is shown in Fig. 42. It is arranged in a manner suitable for measuring the longitudinal vibrations of the milling machine table. The vibrograph rests on the end of the machine table, and the heavy cylindrical weight on the right hand side of the instrument is suspended on flat springs in such a way that longitudinal vibrations of the table cause relative movement between the weight and the body of the instrument. This relative movement is magnified by a lever mechanism and the final record is made by a stylus on a celluloid strip. A second stylus, actuated by a timing mechanism, gives a time record which marks $^1/_{10}$th second at the side of the vibration record. The records can be viewed in a projector and if desired photographic records similar to those in Figs. 13 and 43 can be made.

The records in Fig. 43 show longitudinal vibrations of a milling machine table under cutting conditions when slab milling 2″ wide by $\frac{1}{8}$″ deep with a 4″ diameter 10-tooth cutter. In record (1) the cutter was out of truth, but the high feed rate ensured that each tooth cut, thus giving 10 small vibrations corresponding to each tooth, superimposed on each of the slower vibrations corresponding



(1) Cut 2″ wide × $\frac{1}{8}$″ deep × 6″ per min. feed.
(2) ,, ,, ,, ,, ,, ,, × 3″ per min. feed.
(3) ,, ,, ,, ,, ,, ,, × 3″ per min. feed.
(4) No cut but machine feeding at 3″ per min.

Fig. 43.—Longitudinal vibration of milling machine table under various cutting conditions.

to each revolution of the cutter. When the feed rate was lowered, record (2), the high teeth removed most material, causing four or five larger vibrations at regular intervals and smaller vibrations in between. Record (3) shows that by truing the cutter the vibrations for the same rate of feed were made much more even, and record (4) shows the slight vibration present when the machine was not cutting.

The meter board on the left of Fig. 42 is one of the portable instrument boards used for general power measurements on machine

tools under test. These are replaced by very high precision instruments when special accuracy is required.

One of the main criteria in any finish machining tests, including finish milling, is the quality of surface finish produced. The Research Department has been closely associated with the rapid development of surface finish measurement in Britain during the past five years, and during that period has tested almost every type of surface finish measuring instrument. The surfacemeter now used in the Department is a "Talysurf" which gives pen records of the surface profiles and averagemeter readings of the mean height of the surface irregularities. The analysing head of the instrument is shown diagrammatically in Fig. 44 from which it can be seen that the skid on the left is so long that it always spans several undulations as

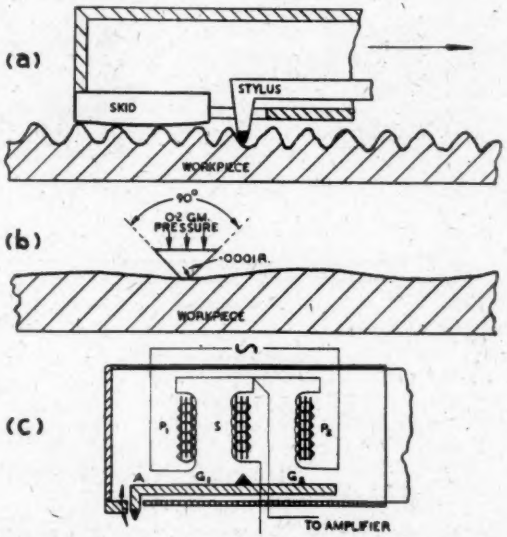
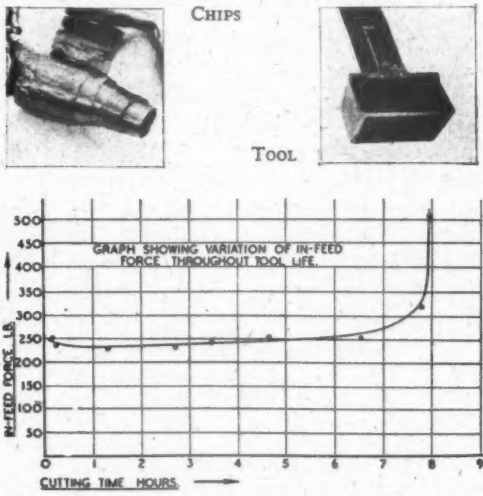


Fig. 44.—Measurement of surface finish by "Talysurf."

it is drawn across the surface, and thus forms a reference line, relative to which the stylus moves as it falls into each hollow and rises over every peak. The irregularities usually present on machined surfaces are not as shown in part (*a*) of Fig. 44, but long and shallow as shown in the diagram (*b*), so that the stylus can usually reach the bottom of each hollow, although its sides form an included angle of 90°. The tip radius on the stylus is 0.0001″ and the pressure of the skid on the surface is approximately 0.2 gm.

When the whole analysing head shown in diagram (*c*), Fig. 44 is drawn across the surface, the skid forms the continuous reference line and the vertical movements of the stylus cause the armature A to rock on its pivot, thus alternately increasing and reducing the gaps G_1 and G_2 and consequently reducing or increasing the flux linkage between primary coils P_1 and P_2 and their common secondary coil S. The resultant variations of the current in S are then amplified and operate either the recording pen or the averagemeter. The recording pen gives records such as those shown in Fig. 14 with vertical magnifications up to 40,000 × and horizontal magnifications of 200 × or 50 ×, and the averagemeter gives $h_{av.}$, the average

MATERIAL TURNED : Ni.Cr. Steel. 233 Br. Cutting Speed. 60 F.P.M. Feed : .0014/Rev. Coolant Soluble Cutting Oil.



Material turned Ni. Cr. Steel. 235 Br. Cutting speed 60 f.p.m. Feed .0014 in. rev. Coolant soluble cutting oil.

Fig. 45.—Form tool tests for the measurement of in-feed forces.

height of the undulations. All the surface finish measurements are expressed in micro-inches (mu. in.), *i.e.*, one-millionth of an inch.

Application of the Results of Production Engineering Research to Industry.

Most engineers will appreciate, without further comment, how results such as those already given in this paper can be directly

applied to production problems. Brief description of a few examples must suffice to further that understanding of the practical application of research results.

An investigation recently carried out by the Research Department for Messrs. A. C. Wickman, Ltd., was to determine the infeed force for form tools, not only when sharp, but throughout tool life. For simplicity a straight form tool, 2in. wide and tipped with 22% tungsten H.S.S. was used. The tool and the chip produced are shown in Fig. 45 together with a graph of infeed force on a base of cutting time. The initial force was approximately 250 lb. for a feed of 0.0014" per rev. and cutting speed of 60 f.p.m. on Ni.Cr. steel of 235 Brinell. For 6½ hours net cutting time the in-feed force remained approximately constant, then rose to 300 lb. after 7½ hours, and finally as the tool became dull rose rapidly to 500 lb. for a cutting time of slightly less than 8 hours.

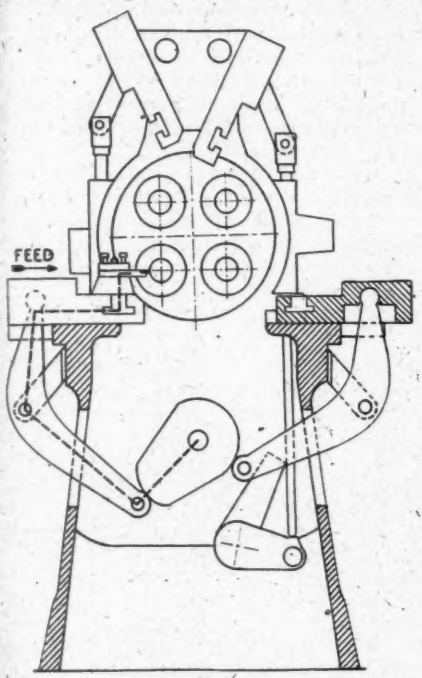


Fig. 46.—Application of form turning test results to multi spindle auto design.

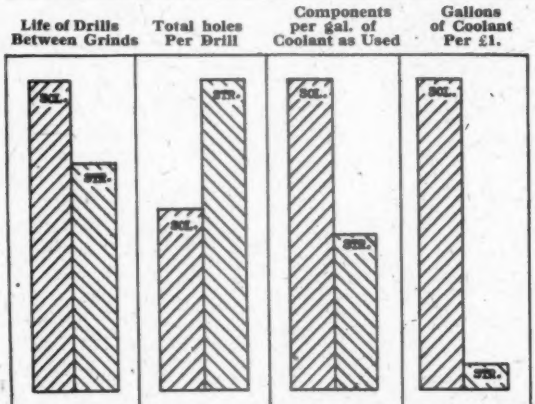
An impression of how such results are applied in the design of machine tools to determine the correct proportions of slides, levers, cams, etc., is given by Fig. 46 which shows diagrammatically by means of the dotted line how this in-feed force is transmitted through various members right back to the bearings and shaft carrying the operating cam.

Results of tests such as those given in figs. 1, 2 and 13 for drilling and milling can be used to select the most economical cutting fluids for specific machining operations. The diagram Fig. 47 shows how such an economic comparison between straight cutting oils and

soluble oils can be based on test results provided all practical factors are given due consideration. Factors purposely omitted from the comparison in Fig. 47 include costs of drills, drill grinding, etc., and effects such as rusting of machine parts.

Vibration tests can often be applied directly in the development of new machine tool designs and in the improvement of existing machines. Records of the horizontal vibrations of the spindle of a diamond turning lathe are given in Fig. 48, which shows that at 1070 r.p.m. the magnitude of vibration is greater than at lower or higher speeds. Such records facilitate the detection of sources of vibration, and their removal by balancing, etc.

As a final example of the application of research results, there is shown in Fig. 49 a special boring bar which, although originally developed for test purposes alone is now capable of direct practical



NOTE.—Comparison is based on observations of a limited range of oils and for severe cutting conditions.
Components per gallon of coolant assumes chips strained and components drained in each case.

Fig. 47.—Economic comparison of straight and soluble cutting oils for drilling.

application. The block B swivels about the pivots S so that the diamond tool D moves in the arc CC, thus aligning facets on the tool with the axis of rotation. Accurate alignment of single facetted tools to a fraction of a degree gives remarkable improvements in surface finish. Similar improvements for external turning were described in references to Figs. 10 and 11.

A factor of considerable general importance in the practical application of research results is the effective presentation of those

HORIZONTAL VIBRATIONS PERPENDICULAR TO MAIN SPINDLE

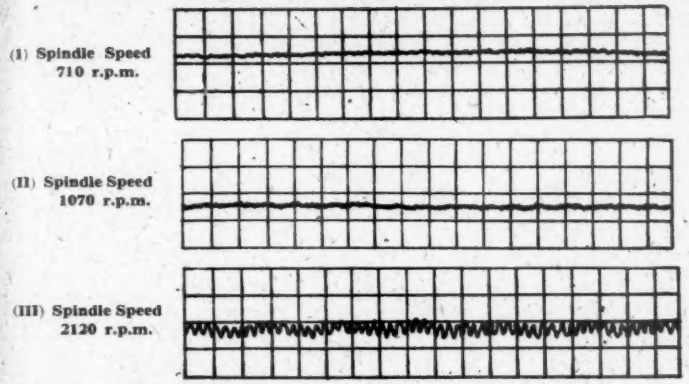


Fig. 48.—Vibration records of diamond turning lathe headstock.

results so that they are understood and can be readily applied not only in large plants, but also in small works, for it should be remembered that small firms comprise the bulk of British Industry. The research workers themselves who contribute a very full share of the effort required to ensure practical application of research results on a national scale, are concerned not only with the identification of the most important problems and their solution, but also with the presentation of results in the most practical form. Numerous attempts have been made to solve this important problem of presentation of results, but we are continually faced with the fact that almost all production processes, including even the apparently simple operation of turning, are complex, so that it is necessary to specify in simple terms the method of efficiently carrying out complex operations. One of the outstanding achievements in this

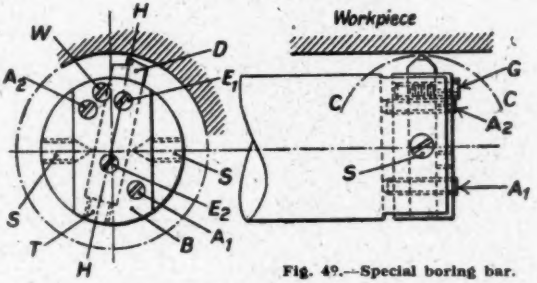
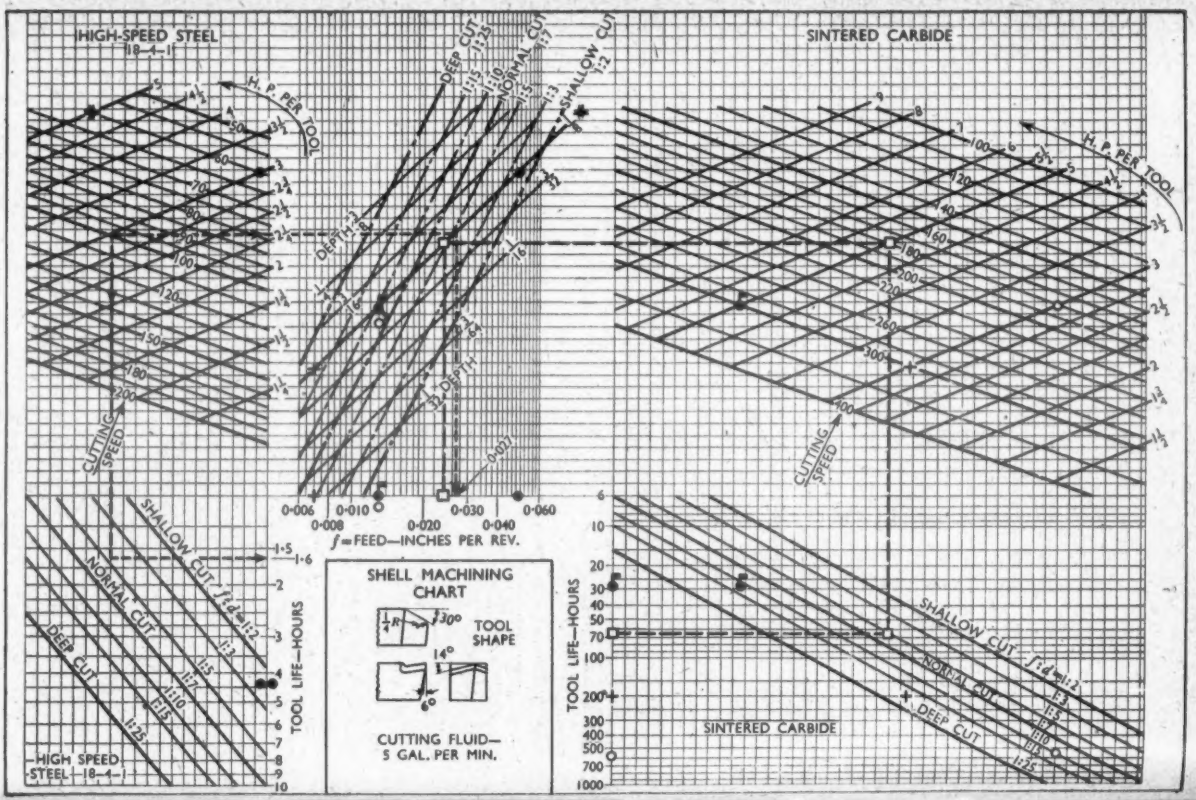


Fig. 49.—Special boring bar.


HIGH-SPEED STEEL
18-4-1
H.P. PER TOOL
CUTTING SPEED
DEEP CUT
NORMAL CUT
SHALLOW CUT
DEPTH
0·006
0·008
0·010
0·020
0·030
0·040
0·060
f = FEED—INCHES PER REV.
TOOL LIFE—HOURS
SHELL MACHINING CHART
TOOL SHAPE
CUTTING FLUID—
5 GAL. PER MIN.
HIGH SPEED STEEL—18-4-1
SINTERED CARBIDE

Example	Tool	No. of tools	H.P. per tool	Speed ft. per min.	Feed in. per rev.	Depth, inches	Tool life, hours	R.p.m.	Machining time, minutes
1	High-speed steel	3	3	100	0.027	0.125	1.6	117	1.12
2	Carbide	3	5	180	0.024	0.125	66	210	0.7

Examples of the use of the chart are indicated by dotted lines.

Fig. 50.—Chart showing relationship between various important factors involved in rough machining operations.

respect was the "Manual on Cutting of Metals" published in 1939 by the American Society of Mechanical Engineers. This manual, which covers the use of single-point lathe tools, gives in tabular form information for the selection of feeds, cutting speeds, etc. Most of the information refers to the use of "18-4-1" high speed steel tools on a variety of steels and cast irons, but this is supplemented by tables covering the use of Stellite and cemented carbides on one grade of steel ("S.A.E. 1020" hot-rolled) and on a medium cast iron. When information is required regarding some particular machining operation involving a combination of tool and material not directly covered by the tabular information, the user must apply a series of multipliers which are also given in tabular form. In this way factors such as relative machineability of ferrous and non-ferrous alloys, effect of tool form, reciprocal influence of tool life and speed, etc., are taken into account.

This method of presenting metal machining data is relatively concise, but the extensive use of correction factors and the necessity for interpolation of variables not governed by linear relations, introduces a degree of mathematical complexity which the practical man must find extremely involved. Moreover, even highly trained engineers when confronted with a mass of tabulated details and complex formulae cannot readily detect important trends in the numerous factors affecting the efficiency of the machining operation.

An alternative, and in many respects more convenient, way of expressing and utilizing the results of practical research in rough machining is by the use of charts such as those adopted by

M. Kronenberg. An example of the type of chart given by Kronenberg in a paper to the A.S.M.E. in 1941 is shown in Fig. 50. Two typical examples, one for high-speed steel tools and one for carbides, showing the co-ordination of machining data, are given below Fig. 50, and the dotted lines indicate how the required information is obtained from the charts.

After selecting the best cutting conditions from the tabulated or charted research results the production engineer has still to set tools and machines to fulfil these conditions. At this point he becomes dependent upon tool makers and machine-tool builders. Unfortunately many machine-tools manufactured today are underpowered and have speed ranges which are ill-chosen and far too low.

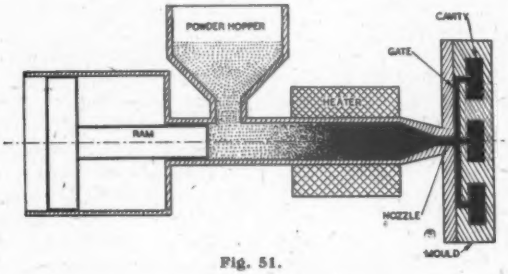


Fig. 51.

Unless machine-tool makers forsee the requirements of the production engineer, the latter may well be positively prevented from machining under the most efficient conditions.

The Future Scope of Production Engineering Research.

An indication of the future of production engineering research is given in the new " Research Plan " recently prepared in the Institution's Research Department. This plan shows that although the work of the Department is intended to continue as a co-ordinated whole, future activities can be conveniently considered in three sections.

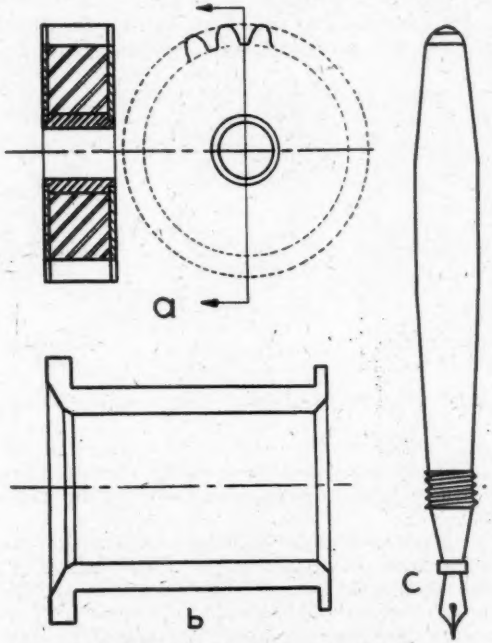
I. *Research in Production Processes* :
   (*a*) conducted in the Research Department,
   (*b*) conducted in Industry.

II. *Production Engineering Library and Information Service* :
   including publications and research intelligence sections.

III. *Production Management Research* :
   (*a*) conducted in the Research Department,
   (*b*) conducted in Industry.

I. Research in Production Processes.

This research will continue to constitute by far the largest part of the Research Department activities, and will be extended, as required, to include all production processes, but for the next few years it is expected that the bulk of work will centre around those processes of most general interest and importance such as metal



(a) Machined plastic idler gear with metal shrouds.
(b) Machined plastic bearing shell.
(c) Plastic fountain pen body. Machining includes thread cutting.

Fig. 52. Machining of plastics

cutting, pressing, manipulation of plastics, foundry practice, die-casting, etc. Some of the investigations will be carried out in the Research Department laboratory, some will take the form of field research carried out in industry, and many will include both laboratory and field research. The services of the research intelligence department (section II), will be utilized before and during all

investigations whether laboratory or field research. Just as production engineering is not in itself an industry, but is common to all industries involving manufacture, so the work of this Research Department will naturally be linked with the activities of other industrial research associations and private research departments. Arrangements are also being made for close collaboration with University research departments as we embark upon the more fundamental aspects of production research. Furthermore, it is not intended to restrict the extent of our contacts and collaboration to Great Britain, but where necessary, to establish and maintain

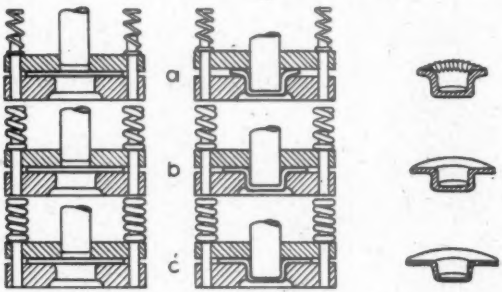


Fig. 53. Effect of pressure plate loading in metal pressing.

contacts with research workers abroad, particularly in the United States of America where much work closely akin to our own has been carried out in progressive industrial research departments and Universities.

The specific investigations for which preparations are being made include, performance of machine tools; performance of cutting tools; machineability of materials; performance of cutting fluids; performance of machine tool bearings; the material, design and finish of machine tool guide surfaces; vibration in machine tools; maintenance of machine tools; temperatures in vital parts of machine tools and in workpieces during machining; precision ball and roller bearings; performance of machine tool drives; foundry practice, including die-casting; chipless forming; woodworking; manupulation of plastics; acceptance test charts for machine tools; surface finish; gauges and measuring instruments; standardisation; and fundamental research on problems such as the nature of machined surfaces, chip flow, loads and deflections of machine tool members, etc.

Future research concerning the practical aspects of tool performance and machine tool performance for metal machining operations

will take the form of an extension of our present activities, but investigations in other production processes will require new equipment and the development of new dynamometers in order that precise measurement can form the sure basis of discrimination. The problems in these other industries are so numerous that very careful consideration will have to be given to priority, so that problems are investigated in the order which will result in the fullest and most immediate benefits to the industries concerned. Examples of typical problems associated with plastics and metal pressings are all that can be included in this paper.

In the plastic industry engineers concerned with the design and use of production equipment are continually confronted by problems such as those illustrated in Figs. 51 and 52. Fig. 51 is a schematic

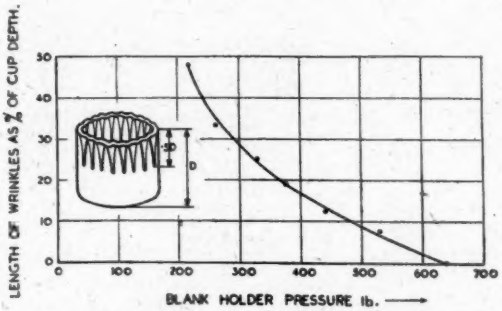


Fig. 54. Effect of blank holder pressure on wrinkling of drawn cups

diagram of an injection moulding machine showing the gates and ram. Dimensions of gates have a considerable influence both on the efficiency of production and on the finished product, and more general information leading to the determination of optimum sizes would be of considerable assistance to the industry. Many other problems surround the development of these machines, not the least of which is the design and use of effective ram packings. In the production of plastic components moulding is frequently followed by other processes such as trimming or polishing or even normal machining operations such as turning. To the production engineer an apparently trivial operation such as trimming a plastic moulding is sometimes of greater economic significance than the moulding process itself and, consequently attainment of high efficiency in this auxiliary process is of considerable importance. Fig. 52 shows three examples of plastic components involving different machining operations. The Research Department has already commenced an investigation on the machining of plastic materials.

Chipless forming provides a field for research as wide and deep as the whole of metal machining research, of which only a small part has been mentioned in this paper. Considering the process of metal pressing alone, industry would derive immense benefits from continuous investigation directed in a practical scientific manner to the solution of those innumerable mechanical and metallurgical problems which profoundly affect the quality of product, efficiency of production, and scope of this increasingly important process. From the casting of the ingot right through the process of rolling and pressing to the finished product a specification of the most effective methods

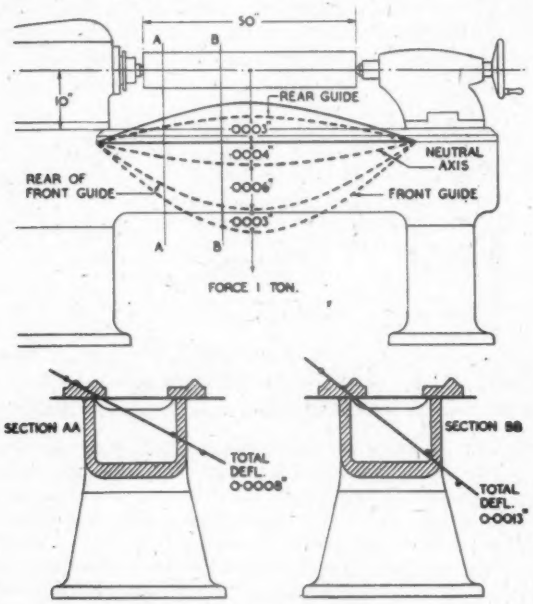


Fig. 55.—Deflections of lathe bed.

of equipment is the constant concern of production engineers. Engineers charged with these responsibilities are keenly aware of the need for solution of problems associated with selection of the best shape, size and disposition of blanks ; selection of most effective and economic lubricants; selection of the best pressure plate loading so as to eliminate wrinkling due to too low pressure or undue strain and cracking due to too high pressure ; selection and application of the

best speed of drawing; and numerous other factors concerning general die design and the machines and materials used in sheet metal pressing, Fig. 53 illustrates some effects of various pressure plate loadings. Section (*a*) shows how insufficient pressure plate loading permits wrinkling; section (*b*) shows how correct loading

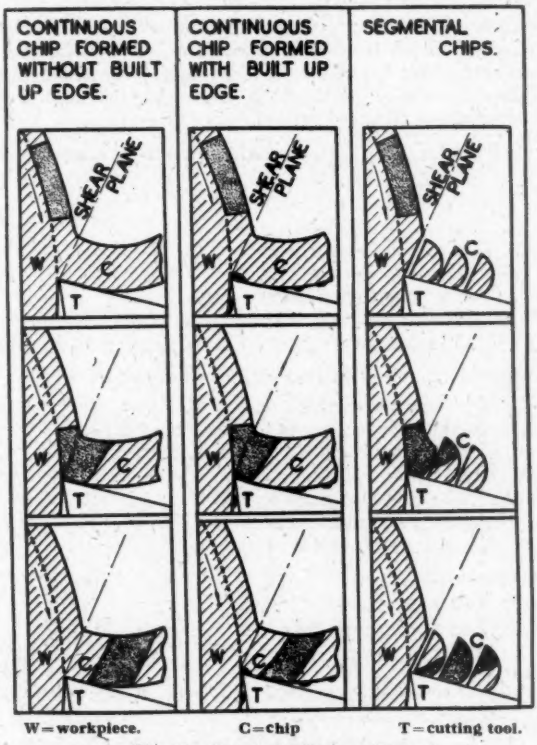


Fig. 56.—Types of chip formation.

gives a satisfactory component; and section (*c*) shows how excessive pressure plate loading causes undesirable straining of the blank as indicated by the fact that the periphery of the blank has been held almost to its original size, while excessive plastic deformation has occured in the free metal below the punch. Results based on experiments carried out by Sachs are shown graphically in Fig. 54 and represent the extension of wrinkling down the sides of a drawn

cup as blank holder pressure is varied. It should be observed that some of the same machining operations preliminary to rolling and pressing, such as those mentioned on page 103 and illustratedin Figs. 16 and 17, have already formed subjects of research in this department.

Two examples of the type of results obtained from fundamental research are given in Figs. 55 and 56. Fig. 55, based on the results of H. Kiekebusch, shows deflection diagrams for a lathe bed under a tool load artificially applied. Fig. 56 is a diagrammatic representation of three types of chip formation. Characteristic conditions which usually contribute to these types of chip formation are as follows :

(1) Continuous chip formed without built-up edge.
- Ductile material.
- Fine feed.
- High cutting speed.
- Large rake angles.
- Sharp cutting edge.
- Very smooth tool face.
- Efficient cutting fluid.
- Tool material giving low friction (*e.g.* carbide or diamond)

(2) Continuous chip formed with built-up edge.
- Ductile material.
- Coarse feed.
- Low cutting speed.
- Small rake angles.
- Dull cutting edge.
- Inefficient cutting fluid.
- High friction at tool face.

(3) Segmental chips.
- Brittle material.
- Low cutting speed.
- Small rake angles.

II. Production Engineering, Library and Information Service.

This section of the Research Department will have four main functions :

(i) *Library.*

The library will provide an up-to-date and fully indexed source of information on all aspects of production engineering. In addition to books, handbooks, journals, transactions of British and foreign engineering societies, and research reports, a comprehensive collection of machine tool catalogues and trade litera-

ture will also be included. Although there is no such library in Britain at present, we have ample evidence of the acute need for such a source of reference.

(*ii*) *Information Service.*

This information service will be a development of the existing scheme whereby members and affiliated firms are given advice on problems which do not necessitate further research.

(*iii*) *Research Intelligence.*

The research intelligence section will prepare production statistics, assemble data required in the standardisation of materials, tools, equipment, etc., and provide information required by the research staff.

(*iv*) *Publications.*

In addition to research reports it is intended that manuals based on results of research and developemnts in practice be prepared for all categories of production engineers, including production managers rate-fixers, inspectors, foremen, etc.

III. Production Management Research.

The research on production engineering processes already carried out in the Research Department or envisaged in part I of this plan, is in many ways inseparably connected with activities, such as rate-fixing, production control, etc., normally regarded as production management functions. It is essential that industry should derive the full benefit of this technical progress by ensuring that management is properly informed and keeps pace with these developments.

The management research section, by its statistical investigations and field research, will maintain the vital link between technical production engineering developments and the various sections of organisation and administration.

The extent to which this section of the Research Department spreads over the field of production management will depend on the demand as revealed by the reports of field research workers who will keep in close touch with production executives.

Even if research facilities are greatly extended and research greatly accelerated, these facts alone will not solve our national problems and produce automatically the great technical advances which must be regarded as a post war essential if Britain is to keep pace with other industrial countries. Research in itself is *not* the aim. Only *effective application* of the results of research will achieve the end we desire. This final step, the application of the results of research, lies in the hands of the works engineers, produ

designers, machine tool and equipment designers, production engineers, etc.

Research results are potential weapons of industry, but they are only useful if they are made available in the right place at the right time. The right place is where the job is planned and carried out, and where the machines, equipment, and tools are made. The right time is usually as early as possible, for in production research we have to face the hard facts of production engineering practice, where the time factor is of paramount importance. Consequently it is sometimes best to plan research so as to give half the answer to any problem in a few weeks rather than the complete answer in several months.

Acknowledgments.

The Research Department is indebted to many firms for their assistance by loans or gifts of machines, equipment and materials, particularly :

Taylor, Taylor & Hobson, Ltd., Leicester.

John Lang & Sons, Ltd., Johnstone, near Glasgow.

Adcock & Shipley, Ltd., Leicester.

Geo. Swift & Sons, Ltd., Halifax.

Thos. Firth & John Brown, Ltd., Sheffield.

The Metropolitan-Vickers Electrical Co. Ltd., Manchester.

Boneham & Turner, Mansfield.

Furthermore, we are deeply indebted to Loughborough College for assistance and facilities which have consitently increased during the past five years.

The author also wishes to record his appreciation of the enthusiastic co-operation of the entire Research Department staff. Only by the patient endeavours of the senior staff is the continuity of this research ensured under the present difficult conditions. Finally, the contribution of the former Director, Dr. G. Schlesinger, to the development of the equipment described above will be manifest.

In developing equipment and carrying out tests such as those described above, frequent reference has been made to the following works :

Benedict and Hershey. 1926 University of Illinois, *An Investigation of Twist Drills*, Part II.

Benedict and Lukens. 1917 University of Illinois, *An Investigation of Twist Drills*, Part I.

Boston and Gilbert. 1936 Trans. A.S.M.E., vol. 58, *The Torque and Thrust of Small Drills Operating in Various Metals.*

Boston and Oxford. 1930 Trans.A.S.M.E., vol. 52, *Power Required to Drill Cast Iron and Steel.*

Boston and Oxford. 1933 Trans. A.S.M.E., vol. 55, *Performance of Cutting Fluids in Drilling Various Metals.*

Ernst, H. 1938 Cincinnati Milling Machine Company (U.S.A.), *Physics of Metal Cutting.*

Ernst, H., and Merchant, M. E. 1941 Cincinnati Milling Machine Company (U.S.A.), *Chip Formation, Friction, and Finish.*

Galloway, D. F. 1943 University of London Thesis, *Fine-finish Turning of Non-ferrous Alloys.*

Kiekebusch, H. 1933 V.D.I. Forschungsheft 360, *Die Werkzeugmaschine unter Last.*

Kronenberg, M. 1941 Mechanical Engineering, vol. 63, *Maximum Shell Production.*

Morris, D. O. 1941 Paper to Australian Institute of Metals, *Machinability of Metals.*

Patkay. 1928 and 1929 Werkstattstechnik, *Bearbeitbarkeit, Bohrarbeit und Spiralbohrer.*

Sachs. 1934-1935 Proc. Inst. Auto. Eng., *New Researches in the Deep Drawing of Cylindrical Shells.*

Schlesinger and Kurrein. 1924 Springer, *Der Ausbau der Einrichtung des Versuchfelders fuer Werkzeugmaschinen an der Technischen Hochschule zu Berlin seit* 1912.

9th October, 1944

Research Department: Production Engineering Abstracts

(Prepared by the Research Department.)

NOTE.—*The Addresses of the publications referred to in these Abstracts may be obtained on application to the Research Department, Loughborough College, Loughborough. Readers applying for information regarding any abstract should give full particulars printed at the head of that abstract including the name and date of the periodical.*

HEAT TREATMENT.

Induction Heating. (*Sheet Metal Industries, March, 1945, Vol. 21, No. 215, 5 pp., 10 figs.*).

Part 6. Internal hardening and assembly processes.

BELTS, DRIVES.

Belt Drive Efficiency, by H. Stuart Jude. (*Power Transmission, 15th March, 1945, Vol. 14, No. 158, 6 pp., 3 figs.*).

An analytical study of the belt drive, with notes on some of the more common inefficencies and their remedies.

Simple Method For Ascertaining Comparable Power Loss By Friction. (*Power Transmission, 15th March, 1945, Vol. 14, No. 158, 2 pp.*).

Notes describing a very simple plan whereby the frictional losses in machines, machine drives, and electric motors can be easily checked by the "basic running-down time" method.

Plant Motorisation, by F. J. Walters and L. V. Levett. (*Mechanical World, 9th March, 1945, Vol. 117, No. 3036, 7 pp., 10 figs.*).

This article describes how a machine shop containing over one hundred belt-driven machine tools was converted to individual motor drive during the annual holiday week when the plant was shut down, and the opportunity was taken of re-arranging the machine tools to give an improved production layout. A motor with an appropriate change-speed unit or drive was added to each machine tool, thus making it completely self-contained. Among the advantages obtained are: (1) Saving in power and hence in fuel. (2) The impossibility of more than one machine being effected by one motor breakdown. (3) Improved working conditions due to : (a) more light, (b) less dirt and dust, (c) less noise. (d) fewer obstructions. (4) Increased safety to operators and maintenance personnel due to absence of rotating shafts and long belt drives. (5) Increased flexibility, allowing a rapid and economical revision of plant layout to suit changes in production. The details of the changeover procedure and the equipment installed are fully dealt with.

LUBRICANTS.

Lubrication. (*Automobile Engineer, January, 1945, Vol. XXXV, No. 458, 3 pp., 1 fig.*).

A review of recent research into problems of lubrication, including newer aspects created by superfinishing.

The Lubricating Properties of Colloidal Graphite, by A. H. Stuart. (*Mechanical World, 30th March, 1945, Vol. 117, No. 3039, 1 p*).

If colloidal graphite is suitably incorporated into a lubricating oil, it is found that a film of graphite, of submicroscopic thickness, is developed on the bearing surfaces. This film cannot be wholly removed except by definite abrasion, and any microscopic irregularities of the surface tend to be smoothed out by the film. The film has a marked attraction for oil, and in the case of a complete breakdown in the oil supply, a graphited surface will of itself provide sufficient lubrication to avoid seizure for a period of many hours.

CASTING, FOUNDRY.

Foundry Sand Testing Handbook (Fifth Edition). (*Book, 1944, 135 pp. Published by the American Foundrymen's Association. B.N.F. Serial 28,079*).

Many of the tentative standards in the previous edition (with a slightly different title, noted in B.N.F. Bulletin 111, July, 1938, p.200) have now joined the long list of A.F.A. standard methods of sand testing. The book is considerably condensed and the layout modified, mainly in bringing descriptions of equipment for various tests under the relevant sections instead of grouping these descriptions together. A short section is added describing dilatometer and gas content tests, etc., which have been recently described in the literature.

(*Communicated by the British Non-Ferrous Metals Research Association*).

The Cast Metals Handbook : Third Edition. (*Book, 1944, 745 pp. Published by the American Foundrymen's Association, Chicago. $6. B.N.F. Serial 27,996*).

Like the previous editions (1935 and 1939) this book aims at providing engineers and designers with a concise survey of the properties and applications of ferrous and non-ferrous castings. The total size has increased from 532 to 745 pages. A large section (very similar to the previous edition) is devoted to the design of castings and to foundry practice, stressing the importance of co-operation between engineers, designers and foundry workers. The sections on steel and iron (531 pp.) are considerably expanded. In the non-ferrous alloys section (94 pp. as compared with 62 pp.) the general information (relating mainly to the alternative casting processes available) is expanded ; there is a detailed classification of the uses of Cu-base alloys ; the discussion of Al-base alloys has been somewhat extended ; while the short sections on Mg base alloys, Pb- base and Sn-base bearing alloys, Zn-base alloys and Ni-base alloys are much as before.

(*Communicated by the British Non-Ferrous Metals Research Association*).

Die Casting Grey Iron in a British Foundry. (*Machinery, 29th March, 1945, Vol. 66, No. 1694, 7 pp., 11 figs.*).

Rights in the Holley process for the die casting of grey iron are held by Qualcast, Ltd., and this article describes their plant and practice. The necessity for maintaining a constant supply of metal without the use of holding furnaces renders inadequate the usual tapping-off methods, and the " siphon-brick " method is used. Continuous rotary-die casting machines are employed with sand-cast dies. Differences from ordinary foundry technique are stressed. Machinability of the grey iron produced compares favourably with that obtained from similar sand castings. It has been found that a saving of 25% of machining time by substituting a die casting for a similar sand-cast article can usually be relied upon, owing to the permissible increases in speed and feed.

A Mechanised Foundry. (*Automobile Engineer, March, 1945, Vol. XXXV, No. 460, 8 pp., 20 figs.*).

The article describes the mechanisation of the Humber Ltd., foundry whereby a 250% increase in production capacity has been obtained from the same superficial area, and with an increase of less than 100% in the labour employed. There are two moulding sections, one for miscellaneous castings such as flywheels and gear boxes, and the other solely for cylinder blocks. Both are fully mechanised. A full description is given of a special fixture used for assembling cylinder block cores ready for insertion in the mould. Reference is also made to the methods employed for controlling material quantity and for testing the finished castings.

MACHINE ELEMENTS, BEARINGS.

Oil Grooves in Plain Bearings, by D. Clayton, D.Sc. (*Power Transmission, 15th March, 1945, Vol. 14, No. 158, 7 pp., 1 fig.*).

Part 2. This deals with results for grooves in the loaded portion of the bush of the apparatus described in the previous part. Test figures are given, and the conclusions are considered in detail.

Bearing Fitting Practice and the Principles of Its Determination, by J. T. Emmerton. (*Power Transmission, 15th March, 1945, Vol. 14, No. 158, 7 pp., 4 figs.*).

The principles and practice of both plain and anti-friction bearings are reviewed. The principles may be summarised as follows : (1) Plain bearings : Fits determined by the need for maintenance of fluid film lubrication ; (2) Ball and cylindrieal roller bearings : Fits have to take into consideration the need to prevent creep and to preserve internal running clearance ; (3) Tapered roller bearings : These are independent of external influences, and the fits can be made the ideal for the operating conditions.

MACHINING.

Machining Zinc Alloys, by W. Bieling. (*Metals and Alloys, May, 1944, Vol. 19, No. 5, 3 pp. Extended abstract from Z.V.D.I., 24th July, 1943, Vol. 87, 4 pp.*).

(Seen in abstract only). Discusses "chippability," a collective term for properties having favourable or unfavourable effect on the formation of chips in machining, under the headings life of tool, cutting power, surface quality and chip formation. Includes table of cutting force vs. degree of drawing for a Zn alloy (no composition) and comparison of volume of chips vs. that of cut material (various non-ferrous and ferrous metals).

(*Communicated by the British Non-Ferrous Metals Research Association*).

Machining of Plastics with Ceramic Tools. (*Plastics, November, 1944, Vol. 90, 509-514 pp.*).

Resume of German investigation on the use of non-metallic tools, translated from Maschinenbau/Der Betrieb, 1938, Vol. 17, pp. 127-130.

(*Communicated by Industrial Diamond Review*).

Turning and Milling with Negative-Rake Tools. (*Machinery, 8th March, 1945, Vol. 66, No. 1691, 5 pp., 8 figs.*).

Examples at the Works of Alfred Herbert, Ltd. are described, following an introductory review of the advantages of negative rake.

Modern Milling Practice and Research. (*Machine Shop Magazine, March, 1945, Vol. 6, No. 3, 8 pp., 6 figs.*).

The average shop must confine itself to cutters which have a fair overall efficiency on a variety of jobs, and this summary is confined to general suggestions which can be utilised in most shops. These are largely concerned with carbide cutters., and cover speeds, feeds and cutter life, and general rules for speed and feed selection. Considerable attention is paid to the proper grinding of carbide cutters, and in addition to recommendations for tooth form and clearance angles, information is given on the selection of grinding wheels.

Method of Spherical Milling, by A. H. Shipley. (*Machinery, 1st March 1945, Vol. 66, No. 1690, 2 pp., 7 figs.*).

The machining of spherical lens grinding and polishing tools.

Drilling Accurately Pitched Holes, by A. Dart. (*Machine Shop Magazine, March, 1945, Vol. 6, No. 3, 3 pp., 7 figs.*).

A method developed to overcome the lack of a jig borer.

New Cooling and Lubricating Method for Drilling. (*Mechanical World, 23rd March, 1945, Vol. 117, No. 3038, 3 pp., 7 figs.*).

When drilling to depths three to four times the hole diameter it is very difficult to protect the cutting edges by the usual methods of lubrication. Even with a plentiful supply of coolant, the hot and compressed swarf often prevents the access of the fluid to the cutting edges. Special drills are used to advantage. In these the coolant is fed through holes in the tool body directly to the cutting edges. Experiements led to the use of compressed air at 84 lb./sq. in. pressure with which was mixed finely distributed oil or oil-emulsion instead of the customery liquid coolant. This met with very good results. The necessary air-emulsion mixture was produced by an atomiser. The results can be summarised as follows : (1) Increased capacity without increased tool wear. (2) Better work. In the reaming of blind holes lubrication with oil vapour has also brought good results. The necessary apparatus is described and test results are given.

Form Grinding. (*Automobile Engineer, March, 1945, Vol. XXXV, No. 460, 3 pp., 6 figs.*).

There have been considerable developments in the use of crush-dressed abrasive wheels for form grinding, and this method of dressing wheels has now been used for applications other than thread grinding. Primarily the crushing technique was developed as a simpler method of producing the desired form on the wheel, but it has proved to have operational advantages that are of even greater importance than the simplification of form production. The principles and advantages of the method are discussed and illustrated by reference to several types of profile and thread grinding machines.

CHIPLESS FORMING.

Extruded Metals. (*Mechanical World, 23rd March, 1945, Vol. 117, No. 3038, 3 pp., 3 figs.*).

Extruded metals have good physical properties and can be produced to close tolerances for the engineering and manufacturing trades. Examples of methods of extrusion are described.

Modern Aspects of Drop Forging, by Hans Haller. (*Translated by R.H.P. Nott*). (*Machinery, 22nd March, 1945, Vol. 66, No. 1693, 5 pp., 13 figs.*).

Part I. Generally speaking, it is usual to adapt the raw material roughly to the shape of the die by drawing ; but this method is only partially successful

because a considerable surplus of material results. To eliminate such waste another process was developed ten years ago in Solingen for small forgings and is termed the " splitting " process. Suitable sections of raw material are cut up in such a way that they approximate closely to the shape of the die and only a slight flash is formed. Examples of the advantages of the splitting process are described and illustrated in detail.

MANUFACTURING METHODS.

Time and Motion Study, by John W. Hendry. (*Automobile Engineer, January, 1945, Vol. XXXV, No. 458, 2 pp.*).

It has been computed that less than 5% of British industry uses time and motion study despite its widespread application in Russia, America, and Germany. Reasons for the neglect include the opposition of Labour on various grounds, the belief that only large firms can benefit, lack of understanding, and the relatively few time study engineers available. Time study is defined as a system of measurement capable of measuring human endeavour. The author describes how it works, and its connection with incentive schemes, and motion study.

Motion Study is the Missing Function, by S. Bloye Dipple, and Brian R. Stephens. (*Machine Shop Magazine, March, 1945, Vol. 6, No. 3, 5 pp., 5 figs.*).

Part 3. Organisation of the motion study department, and in the production shops. Relationship of other departments with time study. The necessity for footrests, good seating, etc.

Body Production. (*Automobile Engineer, January, 1945, Vol. XXXV, No. 458, 6 pp., 7 figs.*).

Methods are described as employed by Vauxhall in preparing for the actual manufacture of pressings for automobile body components. The departmental organisation is discussed, and the methods of preparing models in the pattern shop, and the equipment of the die shop are dealt with. Finally, reference is made to the proving of new dies and to the manner in which the die shop and the production department work in very close co-operation.

Manufacturing the Hercules Piston, by J. A. Oates. (*Aircraft Production, March, 1945, Vol. VII, No. 77, 12 pp., 46 figs.*).

Part I. One of the more important advances in the manufacture of aircraft pistons has been the introduction of the hydraulic deep-pressing technique for the production of blanks, a process which is claimed to result in improved metal structure and a reduction in machining time. The article describes the manner in which one company produces pistons for the well-known 14-cylinder Bristol Hercules sleeve valve engine. This covers stamping, press-forging and machining operations. A feature of the design of this particular piston is the eleven internal and external recesses or pockets, which necessitate approximately half the total machining operations and present some very difficult problems.

MATERIALS, MATERIAL TESTING.

Some Recent Developments in Engineering Materials, by Archibald Black. (*Mechanical Engineering (U.S.A.), February, 1945, Vol. 67, No. 2, 8 pp., 1 fig.*).

Part I. (Ferrous metals). Certain (U.S.) National Emergency steels, introduced because of war shortages of Ni and Cr are here to stay but they will not represent as high a proportion after the war, and the older alloy steels will regain some but not all of the ground lost. A government-sponsored project

is now under way which claims to utilize chrome-nickel-molybdenum scrap in the production of low-alloy moderate-cost steels. From the discovery of "S-curves" came the introduction of the "interrupted quench" and it has become possible to avoid entirely the martensitic condition and obtain a steel that combines hardness and toughness, without the usual alloy additions. As a further development from the foregoing came a method aimed at avoiding the internal stresses that are created in steel by the usual complete quench. One of the troublesome problems in the manufacture of precision gauges has been the fact that tool steels do not attain a condition of stability immediately after hardening. A precision gauge block for example, goes through a stage of growth and distortion extending, normally, over a period of a few years. Various investigations developed the fact that the transformation of high-speed steel becomes more nearly complete if the steel is brought down to a low temperature for a period of a few hours immediately after quenching. Steels have been completely stabilized by this method in periods as short as 48 hours. In addition to providing the vitally important gain in stability, it was also found that the cold treatment has a tendency to produce increased hardness and improved ductility at the same time. Within recent years, it has been made possible to calculate with a good deal of accuracy, the phsyical properties attainable with a steel where the chemical composition and grain size are known, and sample charts and tables are reproduced. There has been made available a group of steels which contain free graphite included in the structure. These steels thus combine certain properties of cast iron (such as easy machining, non scuffing or scoring, and resistance to wear), with the uniform structures, the ready response to heat-treatment, and good physical properties of tool steel. These are now being used for cold-working dies, tools, punches, cams, taps, mandrills, machine parts, etc. Nitriding of stainless steels of the chromium-nickel austenitic type and the straight chromium type is now being done. A method of impregnating the surface of iron and steel with silicon is now in commercial use; its advantages are that of imparting to the steel resistance to corrosion, heat, and wear. The materials capable of treatment include all types of wrought or cast steel with low carbon and sulphur content. An extensive bibliography is given.

Load Calibration Equipment for Testing Machines, by G. L. Brown and H. T. Loxton. (*The Journal of the Institution of Engineers Australia, December, 1944, Vol. 16, No. 12, 5 pp., 9 figs.*).

This paper concerns methods used for the load calibration of all types of testing machines, with comments of the suitability and accuracy of the various means available for this purpose. A brief description is given of standard types of equipment and of a new design of Loop Dynamometer. Special reference is made to the Amsler Standardising Box, and results are recorded of extended investigations which have enabled a great improvement to be made in the accuracy of this instrument.

MEASURING METHODS, INSPECTION.

Magnetic Crack Detection, by J. E. D. Bell. (*Aircraft Engineering, March, 1945, Vol. XVII, No. 193, 3 pp., 12 figs.*).

Part II. Defects and methods of detection are described and illustrated.

SHOP ADMINISTRATION.

Equal Reward for Equal Effort, by F. W. Deakin. (*Machinery, 1st March, 1945, Vol. 66, No. 1690, 2 pp.*).

Reasons for unequal wage levels. Measurement of effort. Catering for the average worker. Time-study quiz., understood by the workers.

SMALL TOOLS.

Selection and Application of Single-Point Tools. (*The Machinist, 10th March, 1945, Vol. 88, No. 48, 12 pp., 11 figs.*).

To obtain maximum production form cutting tools, several points should be kept in mind. Among them are : (1) selection of the right tool for the job, (2) proper tool sharpening, (3) proper use of the tool in the machine, and (4) having enough tools on hand so there will be no loss of machine time for resharpening and replacement. This article reviews all the factors which must be considered for correct tool application. These include : Standardization of tools, nomenclature, cutting angles, etc. Cutting tool materials, carbon, and high-speed steels, cast non-ferrous alloys, and carbides ; Design and application recommendation, tool design factors, chip control, toolholders, etc. ; Methods of tipping tools ; and suggested grinding practices.

Cylindrical Shanks for Boring Bars and Turning Tools, by P. Grodzinski. (*Industrial Diamond Review, February, 1945, Vol. 5, No. 51, 5 pp., 11 figs.*)

Cylindrical shanks are preferred for both boring bars and special turning tools. They permit the tool shank to be rotated about its axis and thus cause a change of the actual cutting angles. This article gives details of methods for the accurate calculation of : Front adjusting angle, real rake angle real clearance angle, and the adjustment of boring tools above centre line. Worked examples are given.

SURFACE, SURFACE TREATMENT.

Replica Method for Evaluating Finish of a Metal Surface, by Harry H. Herschman. (*Mechanical Engineering (U.S.A.), February, 1945, Vol. 67, No. 2, 4 pp., 7 figs.*).

This method of surface analysis is based upon a rapid and accurate procedure for preparing a nearly transparent facsimile of the surface to be evaluated. The fidelity of reproduction of minute surface characteristics in replicas, consisting of a thin film of a suitable plastic, is attested by the fact that such replicas are used in the study of metal microstructures at high magnifications with the electron microscope. The plastic replica was prepared by applying a suitable solvent to the metal surface, following which a strip of clear plastic film was pressed on. The solvent softened the side of the film adjacent to the surface being examined and permitted it to flow and conform under pressure to the minute surface irregularities. The film dried in about 1 min. and then was stripped readily from the surface. The development of an apparatus for evaluating surface roughness, based upon the degree of variation of the geometric characteristics in a nearly transparent replica is described. Evaluations of surface finish made by this method of five specimens which differed significantly in degrees of finish were correlated with profile values of these surfaces determined by (a) the profilometer method (as root-mean-square values), and (b) the microscope on cross sections (peak-to-valley values). These data show that this replica method is especially sensitive for the evaluation of surfaces having high degrees of finish.

The Design and Control of Large Paint Dipping Tanks, by Phillip M. Fisk. (*Sheet Metal Industries, March, 1945, Vol. 21, No. 215, 10 pp., 5 figs.*).

There are, in normal use, three types of dipping tank and conveyors : the V-type, the vertical types with " ram " or drop-hoist dipping, and those with vertical conveyors. These types are described and their relative advantages discussed. Information is given on the collection and re-use of drainings, paint circulation by pumping, the importance of straining devices, relation of viscosity to specific gravity, control methods, thinners, and testing methods.

Electropolishing. (*Mining and Metallurgical Engineering Newsletter, January, 1945*).

(Abstracted from Metals and Alloys, December, 1944). Electropolishing processes are now available in the United States for polishing the common metals, including steel, stainless steel, nickel, copper, aluminium, brass, monel, etc., on a production scale. The most obvious application for electropolishing is finishing for appearance. The polishing of articles of intricate shape, not easily accessible to wheel polishing, is one likely application. The polishing solutions used are of the sulphuric-phosphoric acid types, in some cases also containing chromic or perchloric acid. In some solutions arsenic acid is substituted for phosphoric acid, but the phosphoric acid baths are superior. Full lustre is usually obtained with about 0.001 in. (0.025 ,mm.) metal removal, which requires a processing time of 8 to 30 min. The operating current density is usually 100 to 500 amp. per sq. ft. (1,100 to 5,500 amp./m^2), and the temperature range is 115 to 150°F. (45 to 65°C.). Many other electropolishing solutions have been reported, but it is considered that for broadness of applicability and ease of operation, the sulphuric-phosphoric acid baths are best from a commercial standpoint. There are two classes of baths : (1) those with infinitely long operating life where (a) metal plates out on the cathode at the same rate that it dissolves from the anode, (b) where insoluble metal sulphates form without hindering operation ; and (2) those possessing a finite life and having to be discarded at a dissolved metal concentration of 4 to 5%. Baths which contain chromic acid initially or to which it is added by the work, e.g., stainless steel, have a finite life. Rack design, equipment, etc., are similar to those used for chromium plating. Generators or rectifiers of 12 to 15 v. are needed, though for broadcast use 18 to 24 v. sets may be desirable. Electropolished stainless steel is more corrosion resistant than wheel polished and nitric acid possivated metal. Electropolishing as a machining operation is being used commercially. Electropolishing of a basis metal in preparation for electroplating is of particular advantage where a heavy plate is to be applied for mechanical or engineering reasons. This procedure gives maximum adhesion of the plated metal, since the plate is applied to a strong basis rather than to a weak machined layer. Electrobuffing of plated metals is entirely practical and generally removes no more than 0.0002 in. (0.005 mm.) of metal to achieve full colour.

(*Communicated by the U.S. Office of War Information, London*).

The Pickling of Steels, by Edward W. Mulcahy. (*Sheet Metal Industries, March, 1945, Vol. 21, No. 215, 6 pp., 8 figs.*).

Part V. Lifting and agitating mechanisms are described.

Metal Finishing. (*Sheet Metal Industries, March, 1945, Vol. 21, No. 215, 9 pp., 11 figs.*).

Part 6. Electroplating. Modern equipment and technique for chromium plating. The plating solution. Anode and cathode reactions. Anodes. Plant. Heating. Exhaust equipment. Insulation. Temperature. Efficiency and current density. Throwing power. Pre-treatment before chromium plating. Thickness of deposit. Properties of electrodeposited chromium. Hard chromium plating.

TRANSPORT EQUIPMENT

Flow Packing. (*Mechanical World, 30th March, 1945, Vol. 117, No. 3039, 6 pp., 15 figs.*).

Principles and methods evolved by the Army provide data and experience vaulable to industry for large-scale case packing.

WELDING, BRAZING.

The Welding of Non-Ferous Metals, by E. G. West. (*Sheet Metal Industries, March, 1945, Vol. 21, No. 215, 5 pp., 12 figs.*).

Part 2. Metallurgy of non-ferrous welds—(continued).

Zinc Base Die Castings by E. Christie. (*Welding, March, 1945, Vol. XIII, No. 2, 3 pp., 5 figs.*).

The author explains the problem of welding this type of die casting. He describes the best procedure for repair work by gas welding, and emphasises that this class of repair calls for considerable skill and experience.

Manual Carbon Arc Welding, by P. L. Pocock. (*Welding, March, 1945, Vol. XIII, No. 2, 7 pp., 19 figs.*).

Part 2. The author discusses investigations carried out on different materials and with different joints. Results are tabulated.

Investigations into Manual High-Speed Arc Welding, by E. S. Waddington. (*Sheet Metal Industries, March, 1945, Vol. 21, No. 215, 9 pp.*).

The main factors in welding costs are : (1) Cost of preparation. (2) The welder's time. (3) the cost of the electrode. (4) The cost of current. Of these the most expensive items for normal work are the first two. The cost of preparation can seldom be reduced. With the cost of welder's time, the principal factor is the time of depositing which leaves two alternatives : (a) To provide the welder with machines or devices to weld automatically. (b) To evolve an electrode or a method which will enable the welder to increase his welding speed. The use of automatic welding machines is limited. This investigation deals with manual high-speed welding, and the evolution of a new welding technique. Electrodes employing a type of coating that would allow considerably higher currents to be used, resulted in very high depositing speeds. A large number of fillet and butt welds were made with this material using various well-known makes as a comparison with the high-speed electrodes. In the author's opinion this method of increasing production offers great possibilities, as it can be applied to ordinary plant and equipment and specially skilled welders are not required. The mechanical properties of the joint in question are equal to those obtained by normal methods. Full test data are given.

Experiments on the Effect of Residual Stress on the Strength of Welded Constructions, by J. Orr. (*Transactions of the Institution of Engineers and Shipbuilders in Scotland, February, 1945, Vol. 88, Part 4, 18 pp., 18 figs.*).

It is well known that residual stress may arise to values as high as the yield point of the material, especially where the parts to be welded are restrained. Although the measurement of residual stress has been the subject of investigations, its effect in weakening the resistance of the structure to its service loads has not been seriously considered. It is difficult to arrange tests that will give a definite answer to this problem of the possible importance of residual stress in welded constructions subject to reversed loading, but this paper describes a test arrangement having this objective for a particular set of conditions chosen to simulate, as nearly as possible, service conditions in a ship. The test plates were welded at their ends to contraining frames before the central test weld was formed. The residual stress was measured and the plate was subjected to reversed bending stresses. The conclusions were : (1) A residual stress of 6 tons per sq. in. reduces the fatigue strength by about 17% (when the basis is 200,000 repetitions). (2) An increase of residual

stress above 6 tons per sq. in. causes very little further reduction in fatigue strength. (3) Longitudinal welds made under constraint cause high residual stress accompanied by extensive plastic strains. (4) The fatigue limit as found from large specimens (12 × ⅜ in.) is considerably less than that found from small specimens (1½ × ⅜ in.).

Trends in the Use of Welded Machinery Parts, by Edward J. Charlton. (*Mechanical Engineering (U.S.A.), February, 1945, Vol. 67, No. 2, 11 pp., 35 figs.*).

This discussion of trends in the use of welded machinery parts is limited to components fabricated from low-carbon hot-rolled steel and its related alloys. The basic reasons for trends are due to considerations of cost, reliability, comparative strength characteristics, rigidity, weight reduction, wearability, operating efficiency, and natural adaptability. Examples of jobs coming in these categories are described and illustrated. The remainder of the article is devoted to design criteria and here also examples are given.

Gas Shielded Arc Welding. (*Aircraft Production, March, 1945, Vol. VII, No. 77, 4 pp.*).

A survey of recent developments in the atomic-hydrogen, argon- and helium-shielded processes for welding stainless steel and the light alloys.

Metallic Arc Welding Electrodes. I.—Stainless Steel Electrodes. II.—Surfacing Electrodes. III.—Cast Iron Electrodes, by H. Lawrence. (*Welding J. (J. Amer. Weld. Soc.), November, 1944, Vol. 23, No. 11, 11 p.*).

(I). Describes the various types of stainless steel, their properties and characteristics affecting weldability. Analysis of, and current and voltage ranges for, popular types of electrodes. Compares lime and titania type coatings and indicates the applications of stainless steel electrodes.

(II). Hard surfacing electrodes are divided into six groups : low alloy, manganese steel, high alloy (ferrous), high alloy (non-ferrous), carbides and bronzes. General discussion of these types which are grouped in order of hardness, and resistance to wear, corrosion and impact.

(III). The five types of electrodes for cast iron include Ni-base alloys (e.g., Monel) and Cu-base alloys (e.g., phosphor bronze and aluminium bronze). Technique and applications are described.

(*Communicated by the British Non-Ferrous Metals Research Association*).

Cleaning of Magnesium Surfaces for Satisfactory Spot Welds, by F. Linville and M. Disotell. (*The Machinist, 10th March, 1945, Vol. 88, No. 48, 2 pp.*).

Important phases are presented of various tests which lead to the establishment of techniques for cleaning magnesium. The types of cleaners used and the effects of spot welds on surfaces cleaned with these solutions are also reviewed.

Electric Furnace Brazing Technique, by A. J. T. Eyles. (*Mechanical World, 16th March, 1945, Vol. 117, No. 3037, 5 pp., 11 figs.*).

Uniform tight and clean joints having relatively high strength are possible in controlled atmosphere furnaces. The brazing alloys and fluxes for various applications are described. Electric furnace details and construction are then discussed.

INSTITUTION NOTES

April, 1945

1945.

May Meetings.

11th Eastern Counties Section. Brains Trust, will be held in the Lecture Hall, Electric House, Ipswich, at 7-0 p.m.

12th Yorkshire Graduate Section. Annual General Meeting and "Your Questions Answered," at the Great Northern Hotel, Leeds, preceeded by a luncheon at 1-0 p.m.

14th Derby Sub-Section. Annual General Meeting at 6-30 p.m. Full details to be announced later.

15th Wolverhampton Graduate Section. A lecture will be given by A. Munslow, Esq., on "Pressure Die Casting in Zinc-Base Alloys," at the Walsall Technical College, Wesemore Schools, School Street, Walsall, at 7-0 p.m.

29th Wolverhampton Section. A lecture will be given by D. Dudfield, A.M.I.P.E., at the County Technical College, Wednesbury, at 6-30 p.m. Subject: "Time Study."

North Eastern Senior Section. General Meeting and Works Visit to Messrs. Noble & Lund, Neville Hall Mining Institute, Newcastle-on-Tyne. Details to be announced later.

June Meetings.

19th Wolverhampton Graduate Section. A lecture will be given by Dr. J. D. Jevons, on "Deep Drawing and Pressing," at the Wolverhampton and Staffordshire Technical College, at 7-0 p.m.

26th Wolverhampton Section. A lecture will be given by A. B. Lloyd, A.M.I.P.E., on "The Production of Steel Castings," at Wesemore Schools, Walsall at 6-30 p.m.

July Meetings.

Wolverhampton Graduate Section. Special Meeting for Graduates and Students only (No Visitors) "Brains Trust." Full details to be announced later.

Notes

In the November issue of this Journal the names of the Presidents of the Sydney and Melbourne (Australia) Sections were wrongly given. The correct names are, Sydney, Mr. S. E. Barrett; Melbourne, Mr. H. le Cheminant.

The films which were shown in March to the Derby Section were loaned by the Ministry of Supply through their Machine Tool Control Section, and not by the Ministry of Production as was announced.

Mr. J. E. Farrar has now left Sir Alexander Gibb & Partners and joined Mr. C. Howard Crane to take care of the engineering division of the latter organisation.

The Birmingham Section held a very successful Dinner and Dance at the Botanical Gardens, Edgbaston, on Saturday 18th April, last. Mr. F. C. White, Section President Elect, presided over a large gathering of members, and friends assisted by Mr. E. P. Edwards as Toastmaster. Guests included Sir Robert McLean, President of the Institution, Lord Sempill, A.F.C., Deputy President, Mr. A. Heckle, Midland Controller, Board of Trade, The Lord Mayor of Birmingham with the Lady Mayoress.

The Assistant Secretary (Technical), Mr. F. Gibbons, has resigned his appointment with the Institution.

It is with much pleasure that we record the Decorations conferred on two of our members by His Majesty the King, B. W. M. Wakefield, Esq., M.I.P.E., and Frank H. Moorman, Esq., M.I.P.E., who received the M.B.E. for their Services to the National Production Programme.

Standards Committee.

The Council at their last meeting decided that the Standard Committee should remain in abeyance for the time being. Any queries regarding Standards should be submitted to the British Standards Institution through the Head Office of the Institution.

The Lord Austin Prize.

Through the generosity of Messrs. Joseph Lucas, Ltd., who have given the sum of £112,000 under a seven year covenant to the Birmingham University, this Institution has pleasure in announcing the establishment of a Chair and University Lectureship in Production Engineering.

Newly Elected Members.

As Members: G. W. S. Burdett, J. C. Breakey, E. P. Draffin, C. L. David, G. W. Hartley, L. Holmes, F. C. Jearum, W. Jackson, R. W. Mann, R. E. Rollings, J. B. Samson, C. H. Swift.

As Associate Members: C. B. Abbey, N. L. Akerman, A. E. Ambery, E. W. G. Alexander, O. Ashworth, H. E. J. Butler, W. T. Baird, G. M. Buchanan, H. W. Bennett, J. W. Bennet. H. Bush, W. S. Betteridge, E. R. Booth, J. A. Bailey, H. Bateman, J. S. Bennett, W. F. Chapman, T. Chittenden, D. D. Davis, L. De, H. W. Fairbairn, H. E. J. Farley, A. Greenwood, B. A. Green, J. A. Hayes, A. Hill, R. L. Hitchens, H. Hall, C. C. Jones, C. J. Knott, T. A. Kestell, C. Kingham, R. L. Lewis, H. S. Lovesey, J. Langan, F. W. Lay, B. C. Langhorn, L. H. Milsom, F. H. E. Maidment, L. E. Morris, J. Metcalf, W. J. McLaughlin, A. N. Middleton, J. E. Morris, W. C. Marshall, D. R. Mullen, W. T. Neill, F. G. Phipps, H. H. Plester, F. W. Pridmore, A. Paterson, J. W. Rodger, A. Russell, B. C. Smith, C. Starr, E. Shackleton, W. C. Turner, G. S. Timms, G. Walters, J. L. Wright.

As Associates: H. H. Flatman, E. R. Fryer, H. Teasdale, D. Tiranti.

As Intermediate Associate Members: N. L. Anderson, S. G. Atkinson, W. Butler, N. R. Blackburn, S. R. Burrow, W. R. Bosomworth, J. W. Burrows, H. Barber, A. A. W. Bruce, G. Bell, J. W. Butcher, L. L. Bott, G. W. Cole, S. R. Chatterjee, H. H. Cushing, J. M. Clark, W. Corbett, W. Cumming, J. Dunning, A. S. Downes, W. A. D. Dowsett, D. W. Davis, A. E. Edwards, S. W. Fettes, E. R. Farren, C. J. R. Frazer, N. Gibbon, B. W. Grearson, B. Green, B. H. Geisow, J. W. H. Graydon, H. W. Hardy, R. J. Heppenstall, H. Harriman, N. F. Hale, E. L. Hunter, E. Hoyle, C. Hopkins, E. Hoyland, J. Hogg, G. Head, N. W. Hodgson, W. A. Hodson, C. W. H. Jones, F. Johnson, H. Jones, G. H. Littley, E. O. Loveday, J. Longridge, G. C. Lowe, J. H. McDonald, L. Maguire, G. McConnell, D. O. McGhie, P. H. Muller, C. A. Miller, J. North, G. Nelson, W. J. Pole, J. Padgett, G. P. W. Phillips, E. H. Price, H. Procter, T. Prince, C. R. Parker, D. S. Redhead, E. P. Riley, H. Randle, H. Roberts, J. W. Reynolds, H. G. Rippon, H. Standring, R. C. Stewart, J. Shutt, J. E. Skea, F. Starr, H. M. Smith, G. W. Staniforth, W. J. Thaw, H. A. Tanner, A. J. Thomas, R. L. Taylor, W. P. Town, N. Walker, C. J. V. Walters, S. H. Wood, G. Wood, R. Wearmouth, M. S. Wilcock, M. Woolf, H. Walker.

As Graduates: K. A. Astley, G. W. Ayres, W. R. Bruce, A. G. Bloomer, R. Barnes, D. L. Cohen, E. Evans, N. S. Fisher, G. D. Frier, A. E. Griffiths, L. G. Goode, A. Hamilton, F. Harling, A. Humphrey, H. F. Howell, S. R. Kay, E. R. Landon, L. Ling, G. K. E. McCall, P. D. McCann, F. E. Nichols, K. A. Pollitt, I. L. Robinson, R. N. Rai, A. L. Reid, C. Squire, J. S. Sanders, A. G. Stanton, B. J. Stedman, B. W. G. Savill, R. Tisley, C. K. Trebilcock, R. C. Wood, D. G. Wynn, G. L. Wallach, H. J. C. Weighell.

As Students: G. W. Adams, R. St. Clair Barton, S. Beadle, R. Blacker, I. G. Brydon, D. Buckley, J. A. Bush, D. Chamberlain, J. B. Clayton, W. A. Collins, L. V. Curley, F. K. Derrick, T. E. A. Dicken, R. A. Dimblebee, R. H. B. Dipple, B. E. Downs, D. T. Dunn, T. G. Dunn, E. F. Eskell, D. G. Evans, L. J. Flanagan, I. G. Fletcher, K. J. Foinquinos, T. C. H. Ford, G. H. Giles, E. H. Gill, F. W. Glover, P. E. Goodwin, J. D. Gutteridge, D. M. Hallam, F. Howard, J. Jackson, K. L. Jackson, R. J. Jennings, E. D. Jones, G. C. Jones, G. H. S. Jones, C. M. Jordan, P. D. Kettle, G. R. H. Kilroy, J. Lavin, J. R. C. Leach, F. Lee, L. J. Lewis, S. F. Ling, L. W. Mackintosh, D. J. Main, F. H. Markham, C. G. Middleton, T. M. Mobberley, S. C. Murphy, W. Nugent, Jnr., R. D. Owen, H. A. Palmer, D. J. Parsons, G. D. J. Powell, L. M. Powell, J. Quarmby, F. E. Rattlidge, G. A. Rayden, J. Reed, W. G. Reed, L. N. Rhodes, J. Robinson, P. B. Rogers, J. L. Roper, E. G. Routledge, B. W. Rowland, F. M. Shaw, H. Speak, H. R. Stansfield, D. J. Straight, A. V. Sullivan, P. R. Taylor, S. R. Tyler, B. Waldron, R. Wallis, J. Wardle, W. R. Walton, W. J. Whitehouse, F. Wiles, G. V. Wood, P. Woodward, R. L. Wortley, G. J. Young.

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BOOK REVIEW

An Outline of Industrial Metallurgy, by D. G. P. Paterson, B.Sc., A.R.I.C., and J. Bearn, B.Sc., A.M.I.E.E.

The authors of this book indicate in the Preface that they hope to provide a readable introduction for interested non-specialists, and give some indication of the close link between laboratory and works, and enhance the student's interest in work of a more academic nature.

It is very pleasant to find amongst books of this kind, one in which the authors have achieved their object. Interested readers who are non-specialists in metallurgy are usually engineers, and in most cases their knowledge of the subject is insufficient to enable them to derive much benefit from elaborate equilibrium diagrams and microphotographs.

In this book the authors have endeavoured to convey as much information as possible by illustrations and simple diagrams of which there are a considerable number. They have included approximately 50 microphotographs, but these clearly indicate the points to which reference is made.

One complete chapter is given to the "Interpretation of microstructures," and anyone who is not accustomed to examining microphotographs will find this section extremely helpful.

Two chapters deal with defects in metallic materials, and a further chapter relates to hardening problems. Both of these subjects would require more paper than is at present available if they were to receive complete consideration, but in this book they have been given space in accordance with their value to engineers.

This book is worth reading by all production engineers and should instigate a desire for more complete study of a subject which is too frequently overlooked.

BOOKS RECEIVED

Journal of the Iron and Steel Institute, *No.* 1, 1944, *Vol. XLIX.*

Semi-Rotary Pumps, by British Standards Institution.

This booklet is a handy guide to those interested in the purchase of semi-rotary pumps of this type.

INDEX TO ADVERTISEMENTS

As a war-time measure the advertisement section of this Journal is now published in two editions, A *and* B. *Advertisers' announcements only appear in one edition each month, advertisements in edition* A *alternating with those in edition* B *the following month. This Index gives the page number and edition in which the advertisements appear for the current month.*

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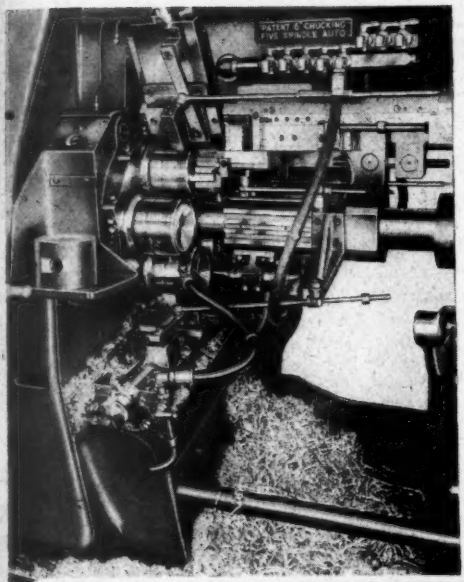

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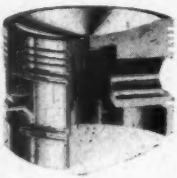

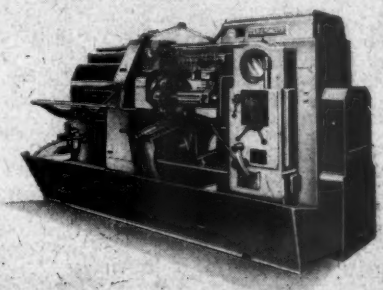

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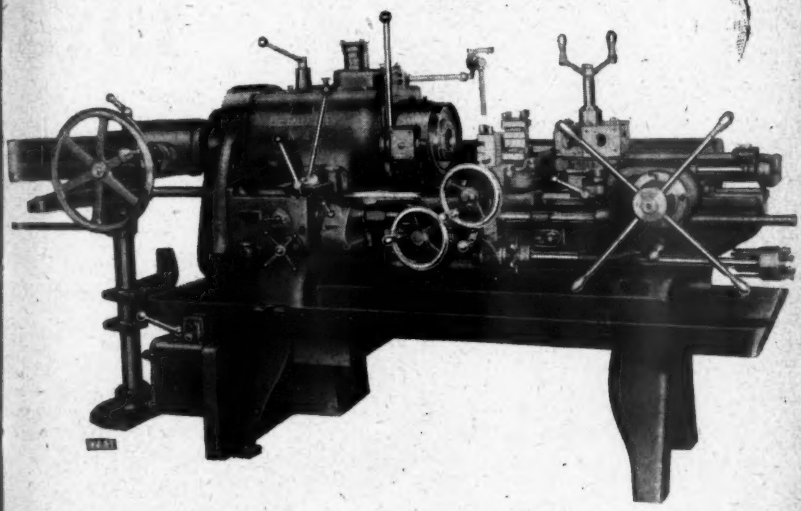

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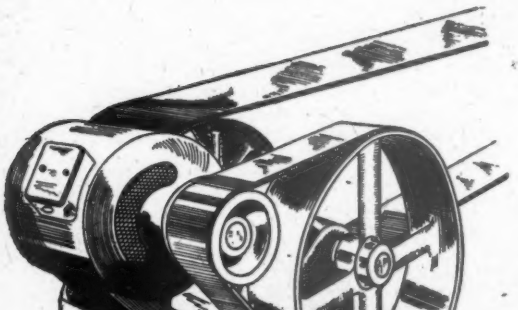

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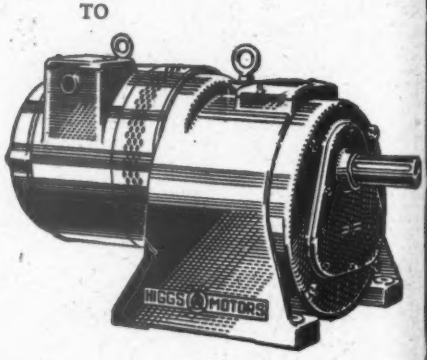

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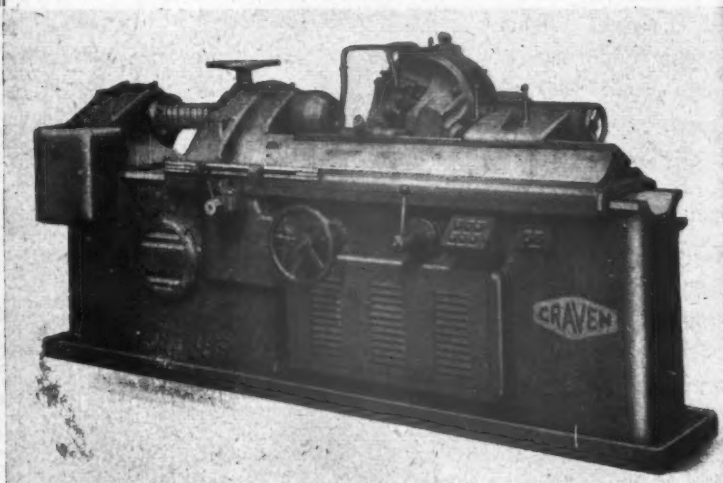

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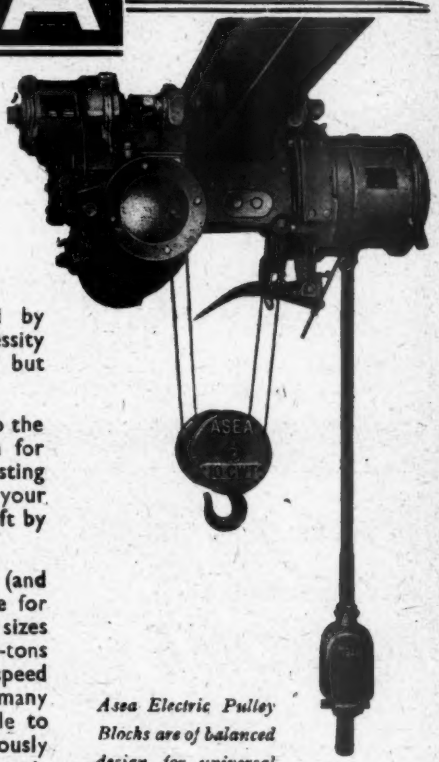

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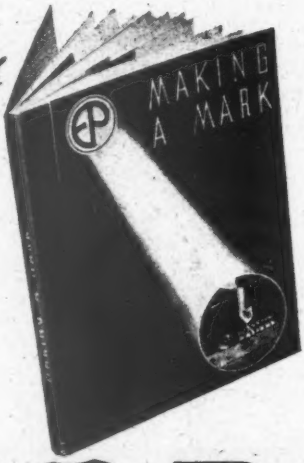

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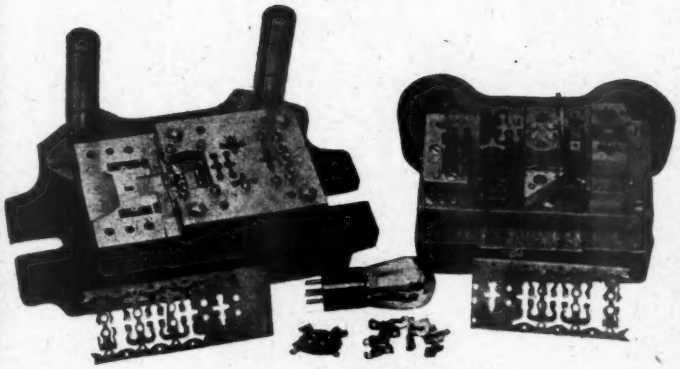

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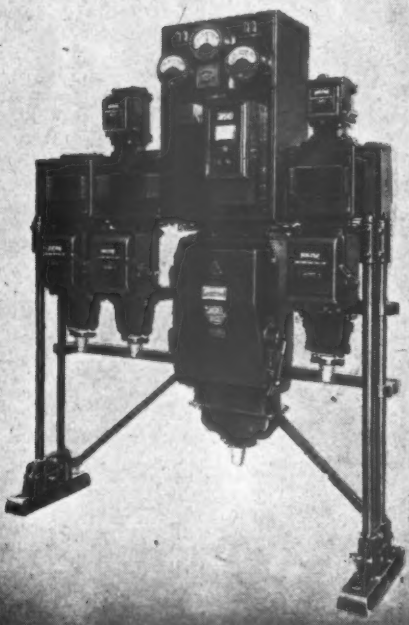

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FRICTION DRIVE. The drive is by friction mechanism operated by means of a dog clutch and hardened lugs on to multiple friction washers. The location of friction drive is below the gears which protect the gears from damage when overstrain is applied to tap.

"ARCHER" FRICTION DRIVE TAPPING CHUCK

Fitted with specially designed DUPLEX Tap Chuck.

Top Jaws for positive drive on Tap Squares.

Lower jaws for centreing Tap Shank.

Both attachments made in three sizes up to $^{3}/_{4}$ in. Whit. capacity.

Eliminates Tap Breakages

ADJUSTABLE FRICTION DRIVE TO SUIT SIZE OF TAP AND MATERIALS

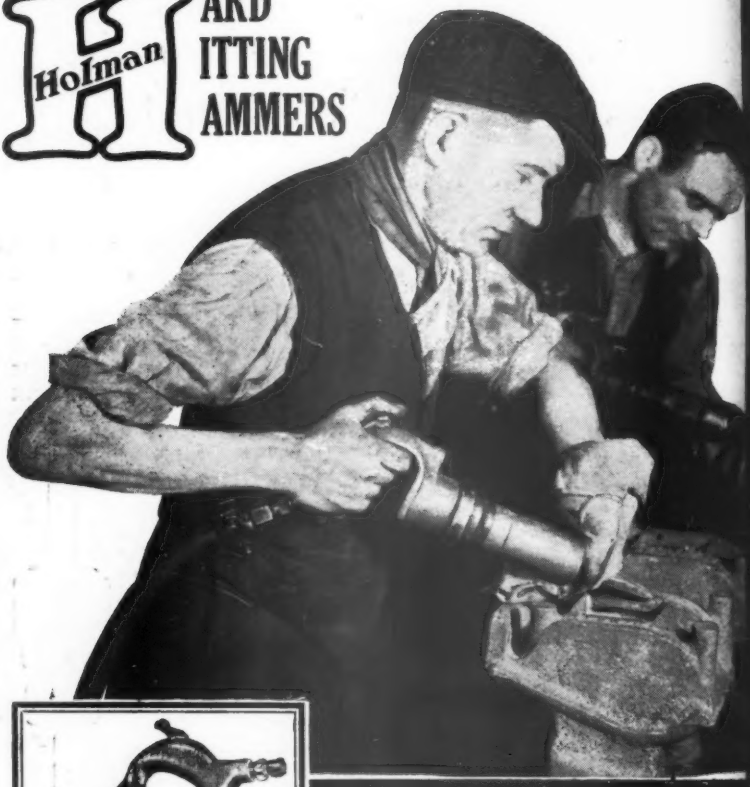
SPECIAL FEATURES. Suitable for tapping either Open or Blind Holes. Will work in Horizontal or Vertical position. Standard Fitter's hand Taps are used.

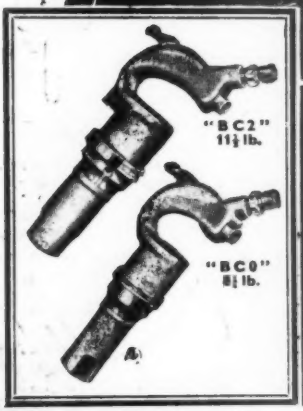
ARCHER SMALL-TOOLS

FRANK GUYLEE & SON, Ltd.

'ARCHER' TOOL WORKS, MILLHOUSES · SHEFFIELD, 8

Holman HARD HITTING HAMMERS





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